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PROFESSOR FRIEDRICH MAX MULLER, LL.D., PRESIDENT OF THE INTERNATIONAL ORIENTAL CONGRESS.—(*From the Illustrated London News.*)

PROFESSOR MAX MULLER.

NEW men and a newer and higher order of things have arisen since the days of "John Company," when civilians of Jos Sedley's type went to India, with small sense of responsibility and abundant contempt for niggers, to "shake the pagoda tree" and bring home the fruit to enjoy at Bath or Cheltenham. The causes of this happier change in enlarged conception of duty to an intelligent subject race are scarcely known to the present generation. The transfer of power from a private company to the imperial government did much; but perhaps the wider knowledge of kinship between East and West—between swarthy Hindu and fair Teuton—in some undetermined degree of blood and more determined degree of language, did more. It is nearly forty years ago since Professor Max Muller, in his famous paper on "Comparative Mythology" ("Oxford Essays," 1856, since republished in the "Chips from a German Workshop"), gave an impetus to the labors of Sir William Jones, Colebrooke, and other almost forgotten Orientalists, which has gathered force with time; and, therefore, it is fitting that he who has contributed so largely to one of the most humanizing movements of our time should again preside over the gathering which recently met in the capital, as the professor well puts it, of "the greatest Oriental empire which the world has ever known."

Professor Friedrich Max Muller, son of Wilhelm Muller, a not undistinguished lyric poet, was born at Dessau on December 6, 1823. After a course of study at Leipzig University, where he took his degree in 1843, he applied himself to the study of comparative philology, mastering Sanskrit, as the then supposed chief key to the relation of the Aryan or Indo-European group of languages. He continued these studies at Berlin under Bopp and Schelling, and at Paris under Eugene Burnouf, collecting materials in both cities for an edition of the sacred hymns of the Brahmans, known as the "Rig-Veda," or "Veda of Praise," the oldest parts of which are computed to date some 2,400 years B. C. Professor Max Muller next came to England to complete his collation of the various manuscripts of these venerable scriptures of an ancient faith. This led to his acquaintance with the well-known scholar and diplomat, the late Baron Bunsen, through whose influence he was engaged by the East India Company to bring out the "Rig-Veda" at their cost. This involved residence at Oxford, with whose university Professor Max Muller has been connected in various honorary and remunerative capacities to the present day, the most important of his appointments being that to the new chair of comparative philology, on its foundation in 1868. Since the year 1844, when he published a translation of the "Hitopadesa," a famous collection of fables, many of which have passed into the folk lore of the West, his pen has never been idle.

On his retirement from his Oxford chair, he undertook the editorship of translations of the "Sacred Books of the East," an interminable series of very unequal importance and value, some of the volumes of which can challenge comparison with the Hebrew or Christian canonical works. But nothing that Professor Max Muller has written can compare in freshness and suggestiveness with his celebrated Royal Institution "Lectures on the Science of Language," or with the scattered essays collected as "Chips from a German Workshop." In most of his recent books, notably his "Gifford Lectures," he has given "out of his treasury" much that is old and very little that is new, ignoring, to the weakening of his permanent influence, evidence brought into prominence by the younger and so-called "anthropological" school of comparative mythologists, for which, oddly enough, he confesses that he has "no taste." And as the professor has committed himself to the well-nigh superseded theory of the Asiatic origin of the Indo-European-speaking peoples, the counter theory of their European origin finds no recognition from him. But, with us all, ideas, like our joints, become rigid with advancing years, and, despite his more recent attitude, the professor has done good service in the circulation of new ideas in the past half century, and in cementing a union between East and West, which pride and prejudice on both sides had long made impossible. Thanks to him and others the doctrine of the correlation of physical forces, which has contributed to our sense of the oneness of the material universe, has its complement in the doctrine of the correlation of languages and of modes of thought, with their manifold outward and visible signs—myths, rites, folk lore, crude or matured philosophies of things—which have revealed the fundamental unity of mankind. It is in this that Oriental studies have rendered exceptional service through the light which they have thrown upon the relations and indebtedness in matters of high import between the nations of antiquity—Greek, Indian, Scythian, Egyptian. But amid the wealth of material brought from the valleys of the Nile and the Euphrates, and from the temples and forests of the remoter East, there is danger of our losing sight of the indebtedness of East to West. Wrapped in speculation on the mysterious, which, too often, was the irrational, the disdainful East shrank from inquiring into causes and origins, and not with her, but with her sister of Greece, is the credit of that cultivation of science which lies at the root of and gives the sap to the spirit of investigation.

The congress, which, in the regretted absence of H. R. H. the Duke of York, was formally opened on September 5 by the Earl of Northbrook, has secured the adhesion and presence of a distinguished body of English and foreign Orientalists. It is matter of deep regret that any schism between men whose work and aims are common should cause the absence of certain representative scholars and the holding of another congress in the south of Europe. But the interest of all intellectually minded people will not be less keen in the objects for which both gatherings are convened. The personal note was wisely absent from Professor Max Muller's address, in which his luminous and picturesque gift of exposition of things not always easy to understand was never seen to better advantage. Perhaps its most striking part was on the intercourse of ancient nations, in the dim period when the Greeks, who were to teach the world so much, learned their alphabet from the Phenicians, who in turn borrowed it from Egypt; when the cuneiform system of writing, invented by people who preceded the Babylonians and Assyrians, was imported into Persia and Armenia, and when there was intercourse between the foreign offices of Egypt and Babylon—the Babylon whose influence on Hebrew literature and religion was wide and lasting.

Remembering the junketings that relieved the serious work of the congress at Stockholm, there is a touch of humor in the gift of a Swedish drinking horn from King Oscar, who thus, Professor Max Muller said at the opening of his address, "has given the members a new proof of his continued interest in the principal object of their congresses—the advancement of sound scholarship."—*Edward Clodd, in the Illustrated London News.*

SAMUEL ALFRED VARLEY.

IT is doubtful whether there lives to-day a man who, considering what he has accomplished, is so little known as Mr. Samuel Alfred Varley. His work has never yet been properly separated from that of his brothers. It is not that Varley was very intimately associated in scientific labors with his brothers. He alone carried out the experiments which led to his inventions. Up to the day of his death, the figure of Mr. Cromwell Varley was familiar in electrical circles; this no doubt, together with the fact that Mr. Samuel Varley rarely mixed or held communication with electrical people, had much to do with his abilities receiving little recognition.

It is hoped that this article will enable living electrical men to see for themselves what the real value is of Varley as an inventor, and to appreciate from the following record the work he has done.

Samuel Alfred Varley was born in London in 1832, and is the third son of the late Cornelius Varley. Cornelius Varley had acquired a knowledge and a taste for science in the laboratory of his uncle Samuel Varley, but he afterward followed the arts, and became distinguished as a painter in water colors. He was one of the original members and founders of the Old Water Color Society.

The Samuel Varley mentioned did much no doubt to awaken the scientific aptitude of the Varley family. In his day he was a leading scientist, and a small body of scientific men and patrons of science, of whom Josiah Wedgwood, the art potter, was one, formed a society, which held its meetings in the laboratory of Samuel Varley. The members of this society afterward founded the Royal Institution. Samuel Varley was invited to become the first professor, but declined. At a later date, he consented, after much persuasion, to enter the service of Earl Stanhope, a great patron of science, where he remained until the death of the earl, who bequeathed to him his scientific library, his tools and apparatus. Some of this apparatus becoming, eventually, the property of Cornelius Varley. They became the playthings of the family, and no doubt did much to inculcate a love of science.

It is not necessary to say much here concerning the brothers of Samuel Alfred Varley. The late Cromwell Fleetwood Varley was perhaps the best known member of a family which has been famous in scientific history for a generation. He was one of the leading electrical men in the early days of electricity, and was during the later years of his life a partner with Prof. Thomson (Lord Kelvin). There will be occasion, in the course of this short sketch, to refer to some of Cromwell Varley's work.

The childhood of Samuel Alfred Varley was remarkable for its rare simplicity. He was reared in a household which had much of the old fashioned about it; but it was an old fashion which proceeded from a love of truth, a devotedness to rectitude, and a desire to live simply and naturally.

Domestic peace and quietude are qualities well suited to the pursuit of scientific knowledge, and amid such surroundings the elder Varley endeavored, hand-in-hand with a knowledge of the Bible, to impart scientific truth to his sons. The family belonged to a religious body renowned for its connection with Faraday. It was a sect composed of the followers of Dr. Sandeman, a seceder from the Presbyterian church. To the meeting house of this simple-minded congregation Samuel Alfred Varley, when a very young child, was taken regularly. Faraday being at that time an elder, Varley was taught to look upon him as a religious teacher and a great scientific man. Naturally there was instilled in the mind of the child an early reverence for Faraday, the effects of which were felt through life. And in all times there is surely no figure which, for its uprightness and singleness of purpose, could command a greater tribute of reverence than the great and good man Faraday.

The day's religious duties over, the rest of the Sunday was commonly devoted to scientific experiments. Then came the frugal evening meal, the Bible was read for a while, and the day was brought to a close by singing some of the grand old hymns.

To the mind of a child thus brought up, religion and science must have been indissolubly associated; the elucidation of scientific truth became a consecrated duty. A noble purpose with which to begin life's battle.

Of Varley's early knowledge, much was gained in his father's studio. His father, while working at the easel, would quote poetry, the child following in a book the printed words. He acquired by this means the ability to read at a very early age. About this time he developed considerable drawing powers, which led the elder Varley to hope that he would one day become a skillful painter. But the drawing faculty became exhausted before the child had reached his seventh year. At the age of eight he was sent to St. Saviour's Grammar School, Southwark, where he remained until his fourteenth year. As a child he was too much given to scientific speculation to take an active interest in routine school work. It is not surprising, therefore, to find that on leaving school he immediately entered into scientific researches. Magnetism appealed to him strongly, and after much experiment he formulated in his own mind a theory of magnetism which of late years he has developed more fully. He was, however, induced to lay aside his magnetic experiments and turn his attention to voltaic batteries.

Between the years 1846 and 1849 he made several hundred Grove's cells for his brother Cromwell, which were intended for electric light experiments. The trouble attendant upon battery manipulation led Samuel Varley to turn to magneto machines as a more hopeful source of energy.

The Saxton machine of that period was a heavy machine, giving comparatively poor results. This want of efficiency seemed to Varley to be owing to the length of the iron armature in which the reversals occurred, and to the middle portion, which was the most active, not being wrapped with convolutions of insulated wire. Thus reasoning, he designed a magneto machine in which the field magnets consisted of bundles of magnetized tempered steel wires, the revolving armatures being made of laminated iron wrapped in the middle. The construction of this machine was commenced when Varley was 17 years of age, but his efforts met with so little encouragement that the machine was afterward abandoned. It is much to be regretted that Varley's work met with so little appreciation, for no doubt his machine would have been a distinct advance on the magneto machines of the period.

But he did not long remain a private experimenter, for in 1852 he entered the Manchester workshops of the Electric Telegraph Company.

At this time there prevailed great activity in the direction of underground circuits. Underground wires were actually being laid. Cromwell, the elder brother of Samuel, was opposed to the adoption of underground circuits, for the reason that induction would be so great that it would interfere with signaling. He was convinced of the reasonableness of this supposition by some experiments which he carried out with the assistance of Samuel on ten miles of wire immersed in tanks. The opinions, however, of the elderly Varley were considered visionary, and the work of laying was continued. The predilections of Cromwell were more than amply verified. Faraday was asked to devise some means of getting rid of the disturbing element, but there was no remedy forthcoming until Cromwell Varley proposed his double current system.

While this may seem somewhat of a digression from the main purpose of our brief summary of the life of S. A. Varley, it will serve to show some of the problems which, remote as they appear to us at the present day, perplexed the minds of the electricians of those days.

The man in charge of a telegraph district needed in those days to be something more than a mere trained engineer. The capacities required of such a man at the present moment need not be so great, but at that time there was no experience to fall back upon, no old and tried engineers ever ready to help a younger confrere over a difficulty. Constantly recurring phenomena, which threw a whole circuit of order, had to be met out of the resources of the engineer in charge. It was an ordeal, however, which, if a man came through, proved him to be an electrician to the backbone. Telegraphy in those days was a new branch of science, struggling hard to maintain its footing as a practical, workable thing.

Much is due to the men who kept it upright; pioneers as they were, they led the way to a practical working and a knowledge of electrical matters. Dwarfed by time as the labors of these men may now be, antiquated as their notions may appear to the new race of electricians, they carried out experiments and perfected inventions which are often claimed in the specifications of to-day. The men of that time were a race of scientific giants, whose magnanimity forbade them to seek out of scientific work personal gain. This is one phase of the matter in which no favorable comparison can be made between the electricians of 1852 and their successors of 1892.

S. A. Varley, in 1854, had engineering charge of the Liverpool telegraph district. The responsibility of such a post is, nowadays, difficult to realize. About this time the first long-distance time ball in connection with Greenwich was erected in Liverpool. For some reason or other, the arrangement worked badly. A discussion arose in the public press, and Varley was called upon to make the apparatus work. He succeeded, at the same time designing an electric chronograph, probably the first of this class of instruments ever made, by which he measured the loss of time in the discharging apparatus, as well as the time occupied by the signal in traveling through an underground wire from London. The apparatus which discharged the ball was also designed to send a signal back to London. The interval of time between signaling from Greenwich and the dropping of the time ball was $\frac{11}{16}$ of a second $\frac{5}{16}$ of a second being consumed in the passage of the signal through the underground wire, and $\frac{6}{16}$ of a second in the London and Liverpool apparatus. Such an accomplishment is nothing extraordinary, but it made a great impression in 1854. The experience gained on the Liverpool time ball enabled Varley some years later to construct apparatus for India, China and elsewhere. There is every reason to believe that in most cases the apparatus is still working.

The year 1854 was a remarkable one in the history of electrical science. The knowledge of the science was then in the hands of a few earnest men. But that year saw many great applications of electrical science; in fact, it marks the beginning of practical applications. Underground circuits of considerable length were first inaugurated, the first long distance time ball was erected, the double current system was first introduced, and in this year the first papers on practical telegraphy were read before the British Association by Cromwell Varley and Edward Bright, and at the same meeting Dr. Wildman Whitehouse (one of the projectors of the first Atlantic enterprise) presented a communication on signaling through long submarine circuits.

With the advent of the Crimean war, there sprang into existence a power which had never before been met with in warfare—the field telegraphs. Previous to the Crimean campaign, all news from the seat of war, all communications between the operating army, were mostly conveyed by mounted messengers; the messages, uncertain in delivery, frequently failing to reach their destination.

The war department were not slow to recognize the utility of the telegraphs, and after communications from the war office, Mr. Varley was appointed the chief of the first field telegraphs. Although in feeble health the greater part of the time he was in the Crimea, he was never absent from duty; he was present at the battle of Tchernayah and the evacuation of Sebastopol. On the armistice being signed, Varley left the Crimea to take charge of the Varna and Constantinople cable. In October, 1856, at the completion

of the Paris treaty, by which peace was restored, he returned to England.

It was then the scientific advisers of the Atlantic Telegraph Company were exercised, among other things, with the question of the size of the conductor. They had determined, by costly experiment, that conductors of small section would transmit signals more rapidly than conductors of larger section. These views were generally accepted, and Faraday went as far as to give an explanation before the Institution of Civil Engineers of the reason small conductors transmitted more rapidly than larger conductors. Instinctively, as it were, Varley felt that such a conclusion was erroneous. He communicated his doubt to the elder Varley (Cromwell), but found that he was in entire agreement with the conclusion of the scientific advisers of the telegraph company. Samuel Varley set to work to elucidate the matter, and after much study and experimenting, detected the source of error. Not only did he put the matter in a clear light, but he demonstrated, also, the general principles underlying rapid transmission.

In February, 1858, the subject of Atlantic telegraphy came up for discussion before the Institution of Civil Engineers. With an invitation to Varley to take part in the debate, came the opportunity of stating his views and the conclusions arrived at from experiment. The weight of argument completely satisfied the engineers present as to the correctness of his experimental results. Mr. Locke, then president, Robert Stephenson and Prof. Graham were warm in their commendations of his work. There was for Varley a still greater triumph, and a further vindication of his views. Faraday, with a magnanimity worthy of such a man, acknowledged, in a letter, the accuracy of Varley's views, thereby admitting the fallacy of his own opinions uttered some twelve months previously.

The paper read before the civil engineers was followed by a communication to the Society of Arts on the practical bearing of the theory of electricity to long submarine electrical circuits. In this paper appears the first description of artificial submarine circuits. By the aid of these circuits the longest submarine cables have been duplexed. This paper, reproduced in most of the technical journals of the period, formed the subject of journalistic discussion in the columns of the *Engineer*, lasting for several weeks. Shortly after Samuel Varley read these two papers his brother Cromwell was appointed chief engineer to the Atlantic Cable Company.

In 1859 Varley re-entered the service of the Electric and International Telegraph Company, as engineer of the London district; it was during this year that Cromwell Varley designed the first of the symmetrical influence machines. This is an interesting fact, because it had an indirect bearing on the future dynamo. It was this machine which awakened in Samuel Varley the desire to make a machine which would do for dynamic electricity what his brother Cromwell's did for static electricity. Unfortunately, he was unable at that time to work much on the original idea, for two years later he was persuaded to resign his appointment as engineer to the London district in order that he might take the management in a manufacturing business inherited by his father, who at that time was an old man, over eighty years of age. Perhaps this was the most unfortunate step in the whole of Varley's life.

It was not until the year 1866 that he was able to complete some of his inventions which had occupied his attention for some years previously. An important invention at this time was an improved construction of needle telegraphs, which were made of soft iron rendered magnetic by permanent magnets outside the coils, and, therefore, undemagnetizable. The coils of these instruments were protected from being fused during thunder storms by a novel form of protector, being, in fact, a lightning bridge. This constructive advance on the Cooke and Wheatstone instrument was referred to in the postmaster general's report as the greatest improvement in needle telegraphs since their introduction. The second invention at this period was the self-exciting dynamo, the first machine made with soft iron magnets. The third invention was a system of electrical communication for signaling between passengers, guards and drivers in railway trains.

It was unquestionably the intention of Varley in this year to have completed his dynamo in time to permit him to read a paper at the Nottingham meeting of the British Association. With this object in view, he worked hard for the consummation of the principle of the dynamo. When he appeared to be in a fair way to declare his invention to the British Association, he was called upon to fit up his system of train communication on the royal train in which Queen Victoria was to proceed to the North. Varley accompanied the royal train to Scotland, proceeding direct from there to Nottingham, where he arrived on the eve of the last day of the meeting. Work of fitting up the Queen's train had thwarted his original plan of reading a paper to the Association. But, disappointing as this was, he felt so confident of the ultimate success of his machine, that he mentioned the matter to Prof. Harley and Mr. Russell, the mathematician, both of whom were present at the meeting. So impressed was Mr. Russell at what he heard, that he strongly urged Varley to read a paper as soon as possible before the Royal Society. This was sound advice, and had Varley made haste to accept it, his claims as the originator of the dynamo principle would have stood absolutely unquestioned. There was ample excuse on Varley's part for not having acted on Mr. Russell's advice; 1866 was the year of the panic, and Varley, as well as thousands more, was involved in considerable pecuniary loss.

Before proceeding further upon the matter of Varley's claims as an inventor of the dynamo principle, it is worthy of mention that Sir Charles Wheatstone was, at the B. A. meeting referred to, president of the mathematical section. In his presidential address there is, curiously enough, no mention made of so important a matter as the production of his dynamo. This fact will be dwelt upon a little later.

Varley's dynamo, now in South Kensington Museum, was completed at the end of August, or the beginning of September, and was immediately shown working to Varley's friends. There is still living a workman who helped to make this machine. The provisional specification was not lodged until December, some months after the completion of the machine. It is, perhaps, worth mentioning that this specification is taken out in the names of Cornelius and Samuel Alfred Varley. This is simply due to the fact that Cornelius and Samuel were at the time in a commercial partnership. But it was pointed out earlier in this article that Samuel Varley had resigned his engineering post in order to take control of his father's business. Cornelius had ceased to take active part in business, and, save in a commercial sense, he was in no way responsible for the patent. It has come within the author's experience that the dynamo of Varley has been sometimes spoken of as the joint production of Cromwell and his brother. Such an error has probably arisen from the fact that the initials only of the patentees have been used, thus causing confusion between Cromwell and Cornelius.*

With the foregoing facts before one, it is not difficult to conceive how important was the advice of Mr. Russell. The delay had simply proved fatal to Varley's claims as the originator of the dynamo principle.

Although there are many who are convinced that Varley was unquestionably the man who had first in his mind the principle of the dynamo, there are others who have shown scant respect to his claims. Books, professedly written as a complete history of the dynamo, pass over his work almost in silence.

It seems to be absolutely certain that Varley worked on his machine some months prior to the British Association meeting. That it was nearly completed is vouched for by the fact that he mentioned the matter to Mr. Russell, and that he exhibited his machines in August or the early days of September is proved by the testimony of his friends.

As Sir Charles Wheatstone was president of the mathematical section, it is curious that he missed the opportunity of referring to his discovery. It may be said that patent rights precluded him from speaking upon the subject. The reply to this is that Sir Charles was absolutely indifferent to patent rights. Why then did he not refer to the matter? The simplest explanation is, that when the British Association met at Nottingham, the dynamo principle was not present in the mind of Sir Charles Wheatstone. Another important point is, that while both the machines of Wheatstone and Siemens were not designed to be self-exciting, that of Varley's most unquestionably was.

Mr. T. E. Gatehouse has, however, so ably dealt with this celebrated dynamo controversy in his "Strange History of a Dynamo" that the subject would gain little from further comments here.

The Railway Regulation Act of 1868 had decided that some system of electrical communication should be adopted on all trains. For the purpose of complying with the clauses of the act, a great trial of systems took place at York. Of all the systems which took part in the trial, Varley's was the only one which completely fulfilled the conditions of the act. He was informed by the manager of the London and North-Western Railway that he might look forward to the work of fitting up all the railway trains north of England. Misfortune, however, still dogged Varley's footsteps. The conservative government went out of office; the new president of the Board of Trade, John Bright, gave to the railway companies a provisional consent to use the cord. This consent was afterward withdrawn, but the railway companies continued to use the cord, and do so at the present day, in defiance of the act of Parliament.

The Telegraph Bill of 1869 made the telegraphs a government monopoly. With it came the power to make or mar a telegraph manufacturer's apparatus. There is no need to inquire closely into the manner of doing this.

It was previously mentioned that the undemagnetizable instruments were much eulogized in the postmaster general's report, but they were not spoken of as the inventions of Varley. The impression was allowed to go forth that it was an improvement which had emanated from the telegraphs department.

The lightning bridges made by Varley were adopted by the post office, but were afterward condemned. They were condemned because the bridges had no direct earth connection. Now, it was an undeniable fact that these lightning bridges were not constructed with an earth connection, because of a regulation of the post office, which was insisted on, and which did not permit Varley to make earth connections.

Soon after the telegraphs became a government monopoly, Varley was compelled to close his works. Thirteen years had been necessary to build up a prosperous business, which in a brief time had become valueless; a cause which can be distinctly traced to the action of the post office.

Shortly after the closing of his works Varley's health gave way, and for some years he was more or less an invalid.

In 1874, Mr. Varley became assistant manager of the British Telegraph Manufactory, and two years later patented a series-shunt or compound-wound machine. Unfortunately, the merits of the machine were not then fully appreciated, and Varley's commercial partners allowed the patent to lapse before the introduction of incandescent lighting had given commercial value to the invention. How well these claims for compound winding have been sustained in three law suits is matter of recent history.

In the month of March, 1878, Gramme applied for a patent for an alternating current dynamo, and 19 days later Wilde lodged a patent for a similar machine. By a method known as racing the seal, letters patent were obtained by Wilde before they had been granted to Gramme. Opposition was then lodged against Gramme's claims, and the matter was taken into the law courts. Rather than undergo the uncertainties of English law, the proprietors of the Gramme patent had resolved to abandon the defense. Varley intervened, advised on the defendant's side, and they resisted Wilde's claims. When the case was called into court, it was allowed to go by default, the plaintiff Wilde paying all costs.

In 1885 Varley was consulted in reference to the law suit of Brush *v.* Crompton & Co. Reluctant though he was at first to take part in a legal controversy, he resolved to do his best to release the industry from royalties. But the lawsuit was compromised in favor of the Brush Company. Varley then called upon the trade to assist him in upsetting the claims of Brush. Messrs. King, Brown & Co. accepted the invitation, and the fight was commenced in the Scotch law courts. Shortly before the case came on for hearing, terms were offered by the Brush Company, and King, Brown & Company's legal advisers recommended their adoption. But Mr. Varley was successful in preventing the compromise, with the result that the Brush Company's claims were resisted in two Scotch courts; and, finally, the House of Lords, without hearing defendant's counsel, gave a similar verdict.

In all probability a compromise would have resulted in the Brush Company obtaining a prolongation of their patent for seven years, dating from May, 1892.

And now that the principal work of Varley's is upon record, we may be allowed to take a rough measure of its value.

Mr. S. A. Varley, through his father (born in 1781), and his father's foster parent, Samuel Varley, reaches back to a period antecedent to that of the discoveries of Galvani, Volta, and Oersted, which were made in 1790, 1800 and 1819 respectively. He has seen nearly all the useful applications of electricity made during his lifetime. He pioneered and constructed in the early days of telegraphy; he had charge of the first field telegraphs ever used in warfare; it fell to him to lay bare the errors of the Atlantic Telegraph Company's advisers; he invented and made the first artificial submarine cables; the one great improvement on Wheatstone's needle telegraph instrument was designed by him, and in 1866 he discovered the dynamo principle, and constructed the first self-exciting dynamo, following this, ten years later, by his compound wound machine.

Through his intervention in the Gramme case, the manufacture of dynamos was thrown open to the industry. His compound machine stopped the exaction of royalties by the Brush corporation. This, the last of his labors, received legalization in the House of Lords on April 5 of this year.

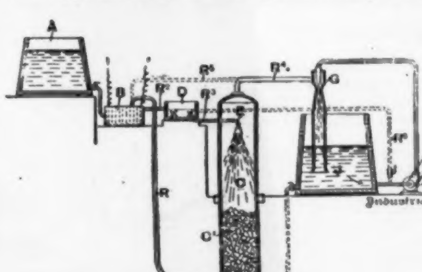
His whole life has been spent in the service of science, yet what is his position to-day? The value of his inventions is undeniable, yet what is his gain? There was never a man in the whole history of invention who obtained less from his genius than Samuel Alfred Varley. There never started on this life a man with greater hopes of his accomplishments. New men have entered the electrical world and speedily become enriched. Varley has toiled nigh fifty years, and to-day is but a poor man. But perhaps the greatest misfortune to him is that his work has received scant recognition.

The fact that Varley did not reap pecuniary advantage from his early invention is a misfortune to the nation. A fair competence would have enabled him to devote his great endowments without intermission to the service of science.—*H. S., in the Electrical Review.*

* A similar error arising from the same source has been met with in other inventions of Varley. The lightning bridge and the undemagnetizable apparatus were often spoken of as joint patents of Cromwell and Samuel Alfred Varley.

ELECTROLYTIC PRODUCTION OF BLEACHING AGENTS.

ACCORDING to this invention, which is by C. Kellner, Vienna, the ions separated by the electrolysis of a metallic chloride are brought into contact with one another outside of the decomposing cell for the formation of hypochlorite, this being effected by allowing



the chlorine to pass off in gaseous form, and then causing it to be absorbed by the solution of a metallic hydrate coming from the cathode compartments. This absorption can be effected either by drawing or forcing the chlorine through an alkaline solution, or by causing an alkaline solution to trickle in a fine state of subdivision toward the chlorine. The chlorine-containing liquid coming from the anode compartments of the decomposing apparatus may also be mingled outside of the apparatus with the liquid passing out of the cathode compartments, but the above-stated employment of the gaseous chlorine is preferable. In any case, however, the alkaline liquid passing from the cathodes must be subjected to violent motion in order that all the bubbles of hydrogen shall be expelled before the liquid is brought into contact with the chlorine gas. The apparatus illustrated diagrammatically herewith can be employed in carrying out this process. The electrolyte is conveyed from the vessel A through a vessel B, where it is electrically decomposed into chlorine gas and caustic soda. The former passes through a pipe R^1 into the bottom of an absorption tower C, containing suitable material to distribute the alkaline liquid, which trickles down from above. The alkaline liquid coming from the cathode compartments, and containing the separated caustic soda, passes through a pipe R^2 into an agitating box D, where any hydrogen bubbles are removed. The said liquid then flows through a pipe R^3 to a rose E, through which it falls and percolates the material C^1, finally passing into the vessel F as finished bleaching liquid. The chlorine gas which is not absorbed in the tower C passes through a pipe R^4 to a water jet blower or injector G, into which it is drawn by liquid that is raised by a pump H from a vessel J, and is forced together with this forcing liquid below the level of the liquid in the vessel J, for the purpose of insuring its being absorbed by such liquid. In paper or pulp mills the

vessel J may be employed for the preliminary bleaching process, by charging it with the pulp that is to be bleached. It may be also employed directly for the production of hypochlorite, by filling it with only so much liquid as will allow the pump to just feed the injector and draw by means of the latter the chlorine directly from the decomposing cell, while the caustic soda is supplied to the suction pipe of the pump by a branch pipe, for which purpose the pipe connections R^5 and R^4 indicated in dotted lines would be suitable.

THE WORKS OF THE SCHULZ-KNAUDT COMPANY, LIMITED.

THE establishment, erected in 1856 by the late Messrs. Carl Julius Schulz and Adolf Knaudt, was started with four puddling and two reheating furnaces and the necessary machinery; at present sixteen puddling furnaces transform into cups the pig iron used by the company as their principal raw material. The company have no steel works of their own; they buy the ingots they require from the makers, who produce them in Siemens-Martin furnaces with basic lining.

In Germany, as a rule, wrought iron is still used on a large scale for boiler making, and the company have always striven to bring the manufacture of wrought iron plates to its highest perfection. They invariably make many tests to control the quality of their material; in the last three months of 1890 about 3,000 tests were executed in their testing house, with the results shown by the following schedule:

	Tensile Strain in Tons per Square Inch. Lengthwise.	Across Fiber.	Elongation in 8 In. Lengthwise. Per cent.	Across Fiber. Per cent.
1st quality...	23	23	23	20
2d " ...	23	22	22	17
3d " ...	22	21	19	13

The rules established by the German Steam Boiler Association exact far less than is given by the figures obtained by the company, especially so far as the cross elongation is regarded; they also admit of a greater difference of tensile strength lengthwise and across the fiber.

The necessary steam is provided by nine boilers of 30 ft. length, 7 ft. diameter, each with an eccentric corrugated furnace of 48 in. diameter; the establishment possesses likewise thirteen boilers heated by the gas escaping from the puddling furnaces, the reheating furnace, and the water gas producer. The total heating surface amounts to 16,000 square feet.

The slabs and ingots are reheated in six Siemens gas furnaces and four other furnaces with solid fuel firing. The first Siemens generator was started in 1871; at present the company have four blocks of four grates each. The forging of the iron slabs is done by two steam hammers of 5 tons each.

The engraving shows that the housing of the hammers consists of two wrought iron pillars with box section girder; this construction was first applied by Messrs. Schulz and Knaudt in 1862.

The principal rolling mill is driven by a reversing engine, which acts upon the rollers by means of toothed wheels geared 1 : 3. Each of the two cylinders is 36 in. in diameter, with 54 in. stroke. There are three pairs of housings, and the length of rollers amounts to 84 in., 115 in., and 138 in. respectively. The latter is fitted with a table with live rollers. The whole arrangement looks strong.

A vertical engine of 43 in. in diameter and 46 in. stroke drives a pair of rolls of 84 in. length; these rolls are in direct connection with the engine shaft. They are only designed for the manufacture of smaller plates. The engine makes about 80 revolutions per minute, and the whole machinery is not based upon the three-high roll system, but consists of two rollers only, having no reversing capacity.

The shearing of plates is done by means of four shears, the strongest of which shears plates up to 1⅜ in. thickness. The blades have a length of 24 in. and an inclination of 4 in. As the machine is driven directly from the steam engine, the number of the strokes of the blade can easily be regulated by means of the throttle valve. The blade is fastened to a counterbalanced casting. The length of the stroke may be altered by putting fitting pieces under the eccentric ram (or lever).

We are informed that this way of shearing is found to be better and cheaper than shearing by the ordinary blades of 7 ft. length and more. This is mainly due to the fact that a great many boiler plates are not sheared to rectangular but to round or curved form; if the latter sizes are required, the blade is regulated so as to give a short stroke only, while it works at a high speed.—*Engineering.*

STEAM HAMMER AT THE WORKS OF THE SCHULZ-KNAUDT CO., LTD., ESSEN.

THE NEW YORK AND NEW JERSEY BRIDGE—ROUTE, UNION STATION AND TERMINALS.*

Preliminary Statement.—The States of New York and New Jersey have granted to the New York and New Jersey Bridge Company full power to construct the bridge, approaches, and stations, and also to make connections with all railroads on the west side of the Hudson River (opposite the city of New York), in the State of New Jersey, and with the railroads coming to the city from the north and east. . . . The Commissioners located the proposed bridge, its connections, and relocated the Union Depot at Forty-second Street, Seventh Avenue and Broadway. All the surveys and borings in the river necessary to determine the practicability of the location have been made. The location of the land pier of the bridge is on the block between Seventieth and Seventy-first Streets, Eleventh and Twelfth Avenues, in New York City, then extending in a direct line with that block across the river to the State of New Jersey, and is believed to be the best location for the public convenience. On the New Jersey side connections are to be made with all railroads that come to the west side of the river. On the New York side the approaches extend southerly from Seventieth Street (between Eleventh and Twelfth Avenues) to Forty-fifth Street, thence curve to the east to the Union Depot at Forty-second Street, Seventh Avenue and Broadway. The approach for the Eastern traffic runs along the Hudson River to a level, and outside of the Hudson River Railroad tracks, to about One Hundred and Fifty-third Street; then running above the tracks of that road, turning to the east so as to reach and make connections with all the railroads from the North and East—thus making unbroken wheel traffic into and through the city of New York to all sections of the country both possible and practicable. The officials of the company are losing no time in preparing the detail plans necessary for the commencement of the great work.

Union Station, Connecting and Terminal Tracks.—The bridge will be connected with the station at Broadway and Forty-second Street by a steel viaduct, whose tracks will be laid upon steel floors, covered with broken stone, so that trains can run with the same speed and absence of noise as on an embankment. Guard timbers like those in use on the elevated roads will prevent derailment of trains. The average height is 60 ft. and the total length about 10,680 ft. The main grade from bridge to station is 0·85 ft. per 100 ft., or 45 ft. per mile.

This new bridge and tunnel scheme is not intended to supersede the existing methods of transferring passengers across the Hudson River, but to increase present facilities by opening a new line, by which passengers coming from all parts of the United States can be set down in the center of New York without change of cars or delays inseparable from crossing by ferries. Still less is it intended to interfere with the present system of handling freight by cars or floats, which reach all parts of the water front of Manhattan Island and Brooklyn. It is proposed to carry only through freight destined for the New England States, and such perishable articles and express freight as are used for immediate consumption.

It is proposed to take two city blocks, each 200 × 800 ft., and bounded by Forty-second, Forty-third, and Forty-fourth Streets, by Seventh Avenue and Broad-

* Extracts from a report to the Commissioners by Mr. T. C. Clarke, Chief Engineer.

way and Eighth Avenue, giving an area of nearly four acres. On this will be erected two buildings, each 200 × 800 ft., connected by a foot bridge over Forty-third Street. These will contain the usual waiting and other rooms and ticket offices, an arrival platform and a departure platform, each of twenty tracks; a terminal hotel, a general receiving and distributing post office for the city, and a house for express and perishable freight—also eighteen stores with their cellars; and about 180 business offices for the railway and for rental. The rentals of these various parts will be sufficient to reduce the rental for purely railway purposes to a small annual sum.

The accompanying plans will show how it is proposed to carry out this scheme. The train shed will be divided into four stories, and the terminal hotel and offices into eleven stories. The upper or arrival platforms, which occupy both buildings, are 36 ft. above the level of Broadway, and incoming passengers can descend both by stairways and elevators. The departure platforms below the arrival ones will be but 9 ft. above Broadway, and passengers will ascend by stairways to the general waiting rooms and ticket offices, which are in the northern building. From thence they will walk on a level, through the waiting lobby to the trains. In the southern building, at the same level, will be a large restaurant, also the dining and reception rooms and offices of the hotel.

Passengers after passing through the gates reach two lobbies, each 40 × 200, connected by a bridge, where they wait until their train is called. Below these lobbies is the passenger baggage room, 28 × 196 ft., to and from which baggage will be taken to and from the trains by elevators. Directly alongside of the baggage room are two driveways, each 54 × 200 ft., one for baggage, the other for cabs, to which passengers come and go from the trains always under cover.

In the northern building below the departure platform a space 194 × 610 ft., with storage cellars below of the same size, has been reserved for a general distributing post office. Mails will be transferred from the trains by elevators, and teams can drive in from the street.

The basement of the southern building on Forty-second Street is intended to contain the express and perishable freight platform. Below it are cellars into which four tracks communicating with the bridge will be run. Freight will be transferred from the cars to the floors above by elevators, and teams can drive in from Eighth Avenue and deliver or take freight. The size is 196 × 610. The storage cellars under the northern building can be used for cold storage.

The space, 96 × 196, between the above described rooms and Broadway, which will be about 4 ft. below street level, can be used in the northern building for shops and stores, of which there is room for eighteen. In the southern building the same space can be used for the kitchen, offices, cafes, etc., of the hotel. Storage cellars of the same size will be placed below. Above the general waiting room there will be nine stories devoted to offices for use of the company or for rental. Above the hotel offices there will be parlors, etc., and eight stories containing from 250 to 300 bedrooms. It is intended that those buildings shall contain under one roof all the requirements of passengers coming from and going to all parts of the country. They will be fireproof throughout, finished in hard wood, and the public room will have marble bases and mosaic floors. The arrival train shed will be covered by an arched steel roof, about 80 ft. above the level of rails. The terminal building will be of stone, the train shed of brick with terra cotta dressing. The departure train room will be 26 ft. high. As locomotives will stand at the outer end, no nuisance from smoke can take place.

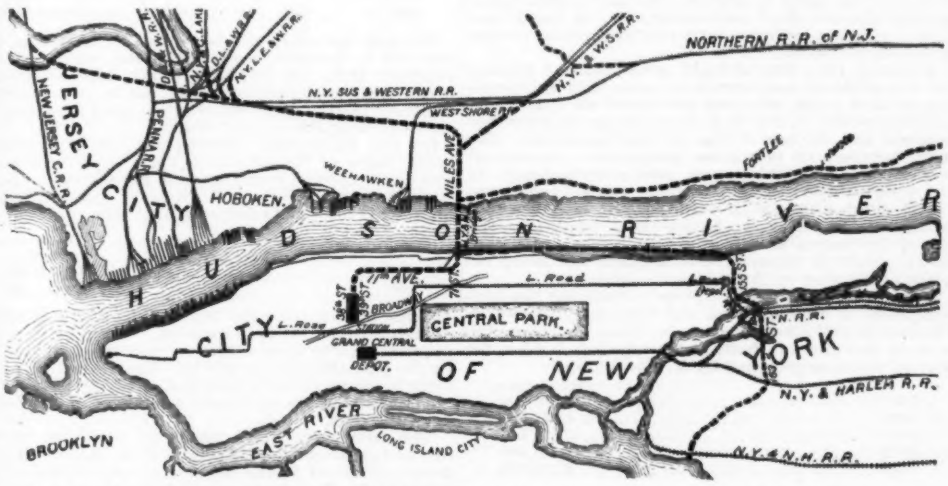
These buildings were designed by Messrs. Creighton Withers and Ernest R. Tilton, architects, of New York, according to a general plan of arrangement given by me, and do much credit to their skill and taste.

From the five great passenger stations in New Jersey, there arrive and depart over 1,000 trains daily. During the busiest hour of each day, 5 to 6 P. M., there arrive 20 to 30 trains, and depart 50 to 60 trains. In the morning hour, from 8 to 9, this order is reversed. If we have 20 arrival and 20 departure tracks, we can handle 60 trains an hour. This allows 20 minutes on every track for a train.

Each departure and arrival platform will contain 20 tracks, or 40 in all. Trains on arriving either from New England or the West will discharge passengers, mails, and baggage, and then back out of the station and go westward to a point on the viaduct between Tenth and Eleventh Avenues. If they are suburban trains, and wanted for immediate return, they will go back without delay to the lower departure platform. In other cases they can either stand upon the viaduct, where there is provided a mile of sidings, or if not required for a longer time, they can recross the river to the storage yard on the top of the Palisades, about 2¼ miles from the station. Here is provided a space of about 100 acres, on which passenger and freight cars can be held and started by gravity if required, thus dispensing with much use of locomotives. The N. Y. C. & H. R. Railroad takes many of its trains to a yard four miles from the Forty-second Street Station. By the use of this system the tracks in the station are never used for storage of trains longer than the time necessary to discharge and take on passengers and baggage.

The number of tracks, as has been stated, will be limited by the number which can pass certain crossing points, of which there are one for incoming and one for outgoing trains. At one and a half minute's headway 40 trains per hour can come in above and 20 go out below, or 60 in all, equal to three trains per hour for each track. The total daily capacity would be 190 express and 600 local trains, or 790 in all. The amount of express business that can be done is limited by the amount of station platform room that can be given. The space provided, we have stated, is 194 × 610 sq. ft. After deducting four tracks or driveways, there remains 94,000 sq. ft. Express freight, and that for immediate consumption, requires but a short time for storage, so that 300 sq. ft. of floor space per car per day is enough.

The tracks are so arranged that each house contains 10 arrival tracks; upon each of these there will arrive 20 trains, or 40 per hour in all. Each house has its own track connecting all the others with the main track. The 20 trains which enter each house go out again as soon as unloaded, to give place to others. Thus there will be 40 crossings of the same point in 60 minutes, giving 1½ minutes' headway for each. This is taken as the ultimate hourly capacity. While the 40 trains are arriving above, and are disposed of outside the house, 20 trains are dispatched from below, making 60 trains per hour in all, and shown in the two busiest hours of the following time table, which gives the ultimate daily capacity:



LOCATION OF THE NEW YORK AND NEW JERSEY BRIDGE—APPROACHES AND RAILROAD CONNECTIONS.

MAXIMUM NUMBER OF DAILY PASSENGER TRAINS IN BOTH DIRECTIONS.

No. of hours.	Trains per hour out.	Trains per hour in.	Total.
1	40	20	60
1	20	40	60
3	30	15	135
3	15	30	135
4	20	10	120
4	10	20	120
8	10	10	160
24	..	..	790

It is intended that all trains for New York shall be taken as far as the storage yard by the locomotives of their own roads, at which point each road can have its own engine house, or there may be a union house for all the roads. From here the trains will be taken by bridge engines, which will be double enders, to obviate the necessity of turn tables on the elevated structures. They will change from one end of a train to the other, as engines on the Manhattan elevated lines do. These engines will take all trains into the New York station and back to the yard. They will also handle all trains to and from the New England roads between the storage yard and Seventy-ninth Street, North River.

A second freight house, 94 × 799 ft., can be placed below the viaduct between Eighth and Ninth Avenues, containing 50,000 sq. ft., exclusive of two driveways or tracks. This will give a total space of 153,000 sq. ft., which, divided by 300, will accommodate 510 cars daily.

In order to avoid another high viaduct running from the bridge level northerly along the west side of Riverside Park, which would be an unsightly object, it is proposed to run through freight trains passing between the West and New England from the bridge end along the viaduct to a point near Tenth Avenue, where they will reverse and move in a northerly direction, descending to the river level under the main tracks by a grade of 30 ft. per mile.

We can now see what the total number of tracks and full capacity of the bridge should be:

	Crossing.
Local trains, New York	600
Express trains, New York	190
	790
Local freight trains: 500 × 2 times ÷ 10 cars per train	100
New England freight: 1,000 cars each way × 2 ÷ 20 cars per train	100
Total	990

Two hundred and forty-eight trains daily on each of four tracks, or about 10 trains per hour.

It is not necessary that freight trains should cross the bridge during the most crowded passenger train hours, so that four tracks can be used for 40 trains per hour one way and 20 another; 60 trains equal to 15 trains per hour on each track hour, or four minutes' headway. This shows that four tracks on the bridge will be enough to do all the business that can be handled in the union station. To provide for future increase it is proposed to design the bridge for four tracks, making the foundations and piers strong enough to carry six tracks. The other two tracks can be added, when required, without delaying traffic, by the mode of construction devised by me.

The maximum number of cars that can cross the bridge daily in both directions on four tracks is as follows:

	Cars.
Local passenger trains, 600 trains, of 5 cars each	3,000
Express passenger trains, 190 trains of 8 cars each	1,520
Local freight trains, 100 of 10 cars each	1,000
New England freight trains, 100 of 20 cars each	2,000
Total	7,520

The addition of two more tracks would add nearly 50 per cent., making the total capacity about 11,000 cars daily in both directions.—*Railroad Gazette.*

HISTORY OF ARTIFICIAL ILLUMINATION.

GAS LIGHTING AT THE PARIS EXPOSITION.*

Apparatus and Progress of Lighting—Non-electric.

REPORT of M. Cornuault, formerly President of the Technical Society of Gas Industry in France and Manager of the Gas Company of Marseilles.

[The Jury of Class 27 was composed of MM. Luchaire, President; Derry, Vice-President; Grouvelle, Reporter (for heating); E. Cornuault, Reporter (for lighting); Beau, Secretary; Kahn, Lacarriere, Chabrie (Victor), Piet and Sainte Claire Deville, Experts.]

INTRODUCTION.

The industry of lighting interests humanity as an entirety.

Man wants to abolish night at his will, in the same manner as, by admirable discoveries, the use of the telegraph and telephone has made it almost possible to abolish distance.

As the sun disappears in the horizon, civilized man has recourse, for the replacing of daylight and prolonging the conditions of social life, to artificial illuminations, the number and intensity of which constantly increases, without being able to assign another limit than the light of day itself—a limit very remote as yet if, according to the works of Bouguer, it is admitted that the quantity of solar light spread around a large city, like Paris, for instance, normally represents more than 10,000 times the value of the entire artificial lighting actually used in that capital.

The industry of lighting is then essentially and indefinitely improvable.

Lighting, properly speaking, is one of the special conquests of the nineteenth century.

Apropos of the Exposition of 1889, which celebrates the centennial of 1789, it might be interesting to rapidly review the progress made in the art of lighting, not only from the last Exposition, but from a century back.

One hundred years ago, or, to be more exact, for several years prior to 1789, the only means of lighting used for a number of centuries, outside of the ancient lamp, was the candle, without any progress, as it were, from one century to another; there were candles of wax for the rich, candles of tallow or perhaps resin for the other classes. The consumption had increased, but the system remained the same. The public lighting in the cities was begun about 1769, by the means of reverberes; that is, a lantern containing an oil lamp, with flat wick, and provided with a reflector, but it was not until 1782 to 1789 that, by the invention and introduction of the Argand lamp, there appeared the veritable transformation which marked the point of distinction between the ancient and modern lighting.

We call to mind that, in an Argand lamp, the wick is circular and the glass chimney, actuating the passage of air in the interior and exterior of the wick, carries the necessary quantity of oxygen for a complete combustion.

In April, 1784, appeared the Argand lamp, with a double current of air, at the Comedie Francaise, where it was seen by the public for the first time.

In the oil feeding, the Argand was provided at the top with a reservoir, either lateral or round, similar to the Astralle lamp.

Until 1800, the Argand lamp remained without a rival. It was at this time that Carcel, remedying the projection of shadow from the reservoir in the Argand, put this at the lower part of the lamp, providing an ingenious clock work movement operating a forcing pump and raising the oil to the level of the wick in proportion to the consumption. Here was a new step, which was successful, thanks to Gagneau (1817), and which constituted an interior lamp sometimes used to this day.

It was about this time that gas lighting, the invention of Lebon, which dated, however, from the latter part of the last century, was veritably in line by first starting with public lighting. Its debut was particularly difficult, and it was only about the year 1830 that it could be considered as established in France by the industry whose intention it was to transform the conditions of public and private lighting.

From 1830 to 1840, while the gas industry was developing, the vegetable oil lamp was being modified.

* Report of the Jury of Class 27. Translated by M. L. Dreher, for *Light, Heat and Power.*

In 1836, Franchot invented the Moderator lamp. The clock work movement of the Carcel or Gagneau lamp was done away with and replaced by the action of a spring on a piston. The simplicity and cheapness of this lamp enabled it to be handled by every one, and its popularity was at once great.

The construction of the vegetable oil lamp had, with this step, given all that it seemed capable of giving, and the successive alterations were applied more to the decoration and shape than to the fundamental parts of the lamp itself.

It is almost solely in this sense that we must note the progress made in apparatus for lighting by vegetable oils presented in the last Universal Expositions, including that of 1889, and we have a tangible proof of this by seeing the large establishment of Gagneau represented in the class of bronzes, instead of in that of lighting.

During the period of 1830 to 1840 the stearic candle was invented, this being industrially manufactured in 1834. It may be said that the period of 1830 to 1840, which witnessed the creation of the Moderator lamp, stearic candle and the development of the gas industry, is memorable, from a lighting point of view, and that the quantity of light put at the disposition of the public notably increased in that time.

From 1840 to 1860, the development of lighting, as mentioned above, continued without any new inventions.

The gas industry, especially at the end of that period, received a new impulse. The uniting of the different gas companies lighting Paris took place in 1855, and the constitution of the great Parisian Gas Company was similarly followed in nearly all the large cities of France, and then in the smaller towns. Gas lighting at this time became a necessity, and the prosperity of the gas companies, so much disputed at first, was a recognized fact.

From 1860 to 1870, the mineral oil lamp, which had already appeared in the preceding period, thanks to Seligne and Menage (1842-45), using the oils of schist of Autun, received a considerable development, proceeding from the discovery of petroleum in the United States, and its enormous exportation, beginning in 1861 and 1862.

The cheapness of petroleum, the absence of all mechanism in the lamp using a volatile liquid, the simplicity and small cost of such lamp, permitted a rapid development and greatly modified private lighting, though almost exclusively among the laboring class, the odor and danger of the oil keeping the rich from its use. The petroleum lamp was also much used for public lighting in towns whose importance did not justify the establishment of gas works, and where these are frequently found to this day.

From 1870 to 1878, the development of lighting, by gas and petroleum principally, was very marked, but the most prominent occurrence was the introduction of a new source of light, the electric light, which, by the luminous intensities which it was capable of emitting, created a new era in the art of lighting.

From 1869, Gramme had rendered industrial the dynamo-electric machine, and, in 1874-75, several workshops in Paris were lighted by voltaic arc regulators, operated by dynamos of a continuous current. These regulators were monophotes; that is, placed separately or deriving power from the same circuit, and giving an intensity from 50 to 100 carcels, and even more, but it was really not until 1878, the year of the last Universal Exposition, that the candle Jablochkoff, making its appearance in the Avenue de l'Opera, and soon afterward in the large stores and on a few public highways, gave electric lighting a start.

From 1878 to 1889, the incandescent lamp made its *debut* (1880). It answered very well for interior lighting, where the intense arc lamp accommodated itself badly, and especially developed from 1887, after the fatal accident at the Opera Comique.

The gas and petroleum industries did not remain inactive.

Concerning the petroleum industry, its development has been characterized by the volume of its importation into France, which has doubled during the last ten years. Not only has the crude petroleum progressed, obtaining products presenting, as it were, less odor, and not igniting above a suitable temperature, to prevent the danger of fire, but the lamp has also received many modifications, and, under the names of Universal lamp, Belgium lamp, Beacon lamp, etc., the use of the double current air lamp has spread more and more. The power of the lamps increased, and lamps of from 3 to 4 carcels and even 8 carcels became common.

Concerning the gas industry in France, production has increased about 50 per cent. during this period. Outside of this progressive development, the chief feature of this period has been the introduction of intense burners, with or without recuperation.

The first intense burner without recuperation was presented to the Exposition of 1878, by M. Sugg, of London.

In 1879, the principle of recuperation was applied to gas burners by F. Siemens, which application rendered the hot air burner of Chaussenot (1836) practicable.

In aiding the combustion of gas by means of air heated by the products of combustion, the temperature of the particles of carbon contained in the flame is raised, and with it the quantity of light emitted according to the rule determined. There is obtained an increase of lighting power with the same consumption of gas, or a less consumption of gas for a determined lighting power. The invention was prolific in results.

The Siemens burner was perfected in England. One of the principal improvements consisted in reversing the flame, the recuperator being placed above.

About 1885 appeared several new types of burners, and under the names of Wenham, Sugg, Cromartie, Siemens, Deselle, Gregoire, Danichewsky, etc., nearly all were represented at the Exposition.

With regard to petroleum, the intensity of the burners constantly increased, and, instead of gas burners of 140 liters, giving the carcel for 127 liters, as the batwing burner, it was possible to successfully obtain intensities of 25, 30 and 50 carcels with the consumption of gas descending to 40 and 30 liters per carcel.

These facts will be given in detail.

The rapid review which we have given is already sufficient to note the progress made in a century. The necessity of light constantly increases, and there will never be sufficient sources of light to satisfy the demands of modern civilization. The field to be explored, as we have said, is indefinite. The progress of electric lighting has excited the general demand and developed, for the good of all, the illumination possible through the other sources of light.

We will divide our detailed examination into three principal parts.

(1) Lighting by vegetable oil.
(2) Lighting by mineral oil.
(3) Lighting by gas.

(1) LIGHTING BY VEGETABLE OIL.

There is but little to add to what has been said, in the first part of this report, on the subject of vegetable oil lighting. The progress which has been made since the last Exposition applies only to the exterior part, and we will go outside of the technical domain to enter more specially into the art of decoration.

A number of exhibitors of Class 27, such as the firms of Bosselut, Parvilliers, Schlossmacher, showed models of good taste and delicacy which deserved gold medals, but, for the reason above mentioned, many of the most artistic and luxurious models were exhibited in the Class 25 (art bronzes), by manufacturers such as Gagneau, Barbedienne, etc.

As to the systems used, they have remained the same since the previous Exposition, adding only the Carcel and Moderator lamps, the latter being almost exclusively used. It would be superfluous to add more than has already been said in the first chapter concerning this lamp, excepting to state that it constitutes a good work lamp, giving a regular, soft light and a very moderate heat, but it must be remembered that, on the one side, the luminous intensities which it is susceptible of practically emitting do not respond to the growing necessities of light of the actual period of today; and, on the other side, it cannot actively compete with the mineral oil or petroleum lamp, the latter being often half again as cheap in consumption, sensibly less expensive in original cost and maintenance, and the absence of all mechanism, besides being capable of giving a luminous intensity far superior to that of the vegetable oil.

Retained, for a time at least, as the lamp of luxury, the vegetable oil lamp could not even hold this privilege in later years, when the petroleum refiners offered purified products, the bad odors being considerably lessened and the use of the oil less dangerous. The manufacturers of petroleum lamps also constructed models of luxury which were used more and more in the homes of the rich, and nothing was left to envy in the Moderator lamp with regard to the elegance and richness in its exterior. Under these conditions, the use of the vegetable oil lamp became less every day, and numbers of these luxurious lamps are being replaced each year by the petroleum lamp.

For want of statistical figures concerning the consumption of vegetable oil for lighting purposes in France, we will give, for example, those figures applicable to the city of Paris, deducting the city tax, for several years, as prepared by M. Fontaine:

	Kilogrammes.
1855	6,894,000
1872	8,951,000
1877	7,871,000
1883	7,451,000
1889	6,180,000

To properly appreciate these figures, we should take into account the population in the years considered. Below is given the consumption per head:

	Kilogrammes.
1855	5·870
1872	4·830
1877	3·850
1883	3·230
1889	2·580

It will be seen that, in 1855, for instance, before the introduction of petroleum and the development of gas, how important a role was played by vegetable oil for the purpose of artificial lighting; but, from that time, far from competing for the increase in the small consumption per inhabitant, which was considerable, the role of the colza oil steadily decreased, notably about 60 per cent. from 1855 to 1889. This fact is corroborated by the decrease in France of the culture of colza and other oily plants used for the manufacture of oil for lighting.

The most important of the plants above mentioned, the colza, has followed the march of culture in France since 1862, the year of the importation of petroleum, as follows:

Areas Devoted to the Cultivation of Colza.

	Hectares.
1862	201,000
1882	92,000
1889	61,000

Thus there is a decrease of 54 per cent. from 1862 to 1882, and 34 per cent. from 1882 to 1889. The total decrease from 1862 to 1889 was over 70 per cent.

It is easily seen that the decrease in the composition of vegetable oil for lighting is constant, it being practically impossible for it to struggle against its growing competitors—petroleum, gas and electricity.

(2) LIGHTING BY MINERAL OIL.

Contrary to what we have stated in regard to the vegetable oil, importance of lighting by mineral oil has constantly increased since the last Exposition.

The tonnages of mineral oils and essences imported and used in France since 1878 were as follows:

	Kilogrammes.
1878	58,930,000
1879	68,601,000
1880	75,019,000
1881	108,785,000
1882	93,134,000
1883	113,175,000
1884	124,127,000
1885	137,976,000
1886	139,497,000
1887	153,613,000
1888	172,942,000
1889	184,101,000
The figures for 1867 were	17,983,000

Therefore, the consumption of petroleum, although its introduction into France dates no further back than 1862, did not cease to develop considerably, and still develops at least from 11 to 12 per cent. per year in the later years, this increase being more than double that of gas, as we shall see.

If the amount of consumption in 1867 (the Exposition year) is taken as a basis of comparison (say about 18,000 tons), it will be seen that the figures more than trebled in 1878, and increased tenfold in 1889, without the population in France having sensibly increased. The mean consumption per inhabitant, taking into account the population, was:

	Kilogrammes.
1867	0·47
1872	1·18
1878	1·60
1883	2·90
1888	4·50
1889	4·80

It is interesting to take account of what these figures represent as light and relatively compare them with gas light.

A consumption of 35 to 40 grammes of petroleum per carcel per hour can be admitted, or, to conform with the decisions of Congress of 1889, 4 grammes per candle decimal hour. Under these conditions, the quantity of light produced by the consumption of petroleum, as above mentioned, deduction being made for the quantity of petroleum used other than for lighting, approximately valued, would have been:

	Candle Decimal hour.
1867	4,250,000,000
1878	13,990,000,000
1888	41,090,000,000
1889	43,700,000,000

Following is given the consumption of gas in France in the comparable years:

	Cubic Meters.
1878	382,000,000
1888	617,000,000

To these figures should be added, to be precise, the gas used in factories, work shops, etc., which are not supplied from the city gas works, but by private plants; this consumption could not be given exactly, but their relative importance is too small to materially alter the comparison given below.

On the whole, the consumption given, deduction being made of the quantity of gas used for heating and motive power, resulting from the summary values, equivalent at the rate of 110 liters, at least, per carcel hour, or 11 liters per candle decimal hour, is:

	Candle Decimal hour.
1878	30,000,000,000
1888	47,000,000,000

These figures show the importance of the quantity of light furnished by petroleum, which, by its rapid progress, nearly approaches the volume of light given by the gas, although in 1878 the light given by petroleum was only equal to half that given by gas.

The distribution of these two modes of lighting is very different.

The petroleum, which needs no works, no piping, can be introduced equally as well in isolated habitations and small towns as in the large cities, and is adapted to the entire population, whereas the gas, which enters in populous centers or in large cities, adapts itself to but one-third of the population of France, as: Out of 36,121 towns in France, with a population of from 2,000 to 4,000 inhabitants each, only 1,028 towns use gas.

Thus, there are a number of small towns, villages, etc., which owe their public and private lighting to petroleum.

The development and consumption of petroleum kept steadily on in France, despite its high price, due to the duty and city tax imposed upon it. These taxes were, nevertheless, impediments, as may be seen from the fact that the consumption per inhabitant, in Berlin, for instance, is nearly five times that of Paris, while Belgium proportionally consumes four times as much petroleum as France.

Of course, the difference in price is not alone accountable. The different conditions of life in the two countries must be taken into consideration; Belgium being industrial and France agricultural.

Having rapidly reviewed the successive improvements in the mineral oil lamp, it now remains to look more specially into the improvements made since the Universal Exposition of 1878.

The essential parts of the petroleum lamp were derived from those of the lamp which Menage rendered practical in 1842, by the use of the metallic disk placed in the center of the flame, forcing the air to traverse it and burn the carbon of the rich hydrocarbon.

The first petroleum lamps imported from America at the same time as the product itself, in 1861 and 1862, were with flat wicks, the entrance cap being raised higher than the wick, to form the chamber of combustion. The flat burner, in use to this day, was specially adaptable by its great simplicity, but to procure a light of greater power it was necessary to return to the circular wick of Argand with the interior current of air. In 1862, Maris patented a lamp with a central current of air traversing the liquid and having a metallic disk.

In 1868, there was introduced in France the round burner, with narrow chimney, called the Allemand burner. The extremely small cost of these burners (about 6 to 9 francs per dozen) rapidly developed their sale. In this year, also, Doty applied the entrance cap to the petroleum lamps, surmounting the wick and the central chimney. This system, somewhat modified, was adopted in 1874, by the administration of beacon lights. Since that time, the central disk has been dropped, although the cap has been retained.

From 1868 to 1878 numerous experiments were made with burners giving superior intensity, of which is specially notable the multiple wick burner, manufactured by Girardin and due to Defienne (1867), called the mitrailleuse burner. It was composed of a central tube for the passage of air, around which were grouped a series of small wick tubes, round and solid. This burner gave a light of from 2 to 2¼ carcels, but the

regulation of the wicks was very difficult. There is also the Besnard lamp, exhibited in 1878, which gives, with a central current of air and narrow chimney, a light of from 2 to 3 carcels.

But it was really not until the introduction of electric light, and especially since the popularity of the high power gas burners, first without recuperation, then with recuperation, that is, after 1880, that the manufacturers of petroleum lamps exerted themselves to produce lights of greater power, the need of which did not make itself felt until then, and it was not until 1885 that they were commonly used in France. The chief lamps patented—Belgium lamps, Universal French lamps, Beacon lamps, etc., are nothing more or less than the primitive types of lamps with double currents of air, the proportions, however, of all the parts of the lamp and burner being judiciously chosen and minutely studied by the best manufacturers.

We will give the most recent types exhibited at the exposition.

The Beacon lamps of Besnard lighted the press pavilion at the exposition. This lamp has a double current of air. One of these currents is produced by a conical chimney proceeding from the lower part of the lamp, the bottom of which is raised by means of small spheres above the surface of the support, and bordering on the axis of the cylindrical wick; the other current is conducted to the exterior of the flame by a round cap placed above the wick, and by a steel disk placed in the center. The glass chimney is cylindrical, with the inflated part around the flame. These lamps were tested at the municipal laboratory for the testing of gas in Paris by M. Lemoine, chief of the office, who obtained the following figures:

	Consumption of Petroleum per Hour.	Intensity in Carcels.	Consumption of Petroleum per Carcel Hour
Lamps of 14 lines..	17 gr.	2·54	30·3 gr.
" " 24 " ..	113 "	3·43	30·9 "
" " 36 " ..	523 "	6·85	32·6 "

The Hinks or Duplex Lamp, of Birmingham.—The burner of this lamp is composed of two old style burners with flat wicks. Each wick works separately by means of a double button, and is provided with an extinguisher, a movable envelope, which, as it is raised, intercepts the flow of air. The lamp can be lighted without lifting off the chimney, by the rotation of a lever key, which raises the chimney holder and chimney at the same time. The Hinks burners are voluminous, and require chimneys much inflated, necessitating special globes. These constitute the mechanical improvements mentioned, which do not concern the power of lights nor the cost of the burner, which made it so popular. The Hinks lamp can be considered as the first petroleum lamp of luxury. Rich models of all kinds were made and sold, especially the stand lamp of various forms and styles.

The test of its intensity made in the laboratory of the gas pavilion, under the direction of M. Sainte Claire Deville, gave an average hourly consumption of 78 grains of petroleum for an average intensity of 2·14 carcels, for six consecutive hours. The power began to decrease at the end of the third hour. The average consumption per carcel hour was 36·4 gr.

We have just spoken of the average intensity. This means that, for the comparative tests of oil lamps, either vegetable or mineral, where the alimentation is necessarily not continuous, like that of the gas, for instance, it does not suffice to make but one photometric test of the light, but is necessary to make successive tests at different periods, and to note the curve which follows the luminous intensity during the actual time of the normal lighting of the lamp.

It was thus that a series of lamps were operated upon in the gas pavilion laboratory. The lamp being filled with oil and weighed, is lighted and the first photometric test is made; then, after each hour of lighting, again weighed and tested, and so on until extinct.

There is obtained, therefore, a diagram, by carrying the intensities in ordinates, and the time in abscisses. The operation of the lamp is read on the indexed curve, and the respective qualities of the different types of lamps can be easily estimated.

The Rochester lamp, of New York, is also a lamp of luxury, has a double current of air and a round wick; the central disk is replaced by a cover of wire gauze, through which the air brought by the central air current is heated, giving whiteness to the flame.

The Sepulcher lamp, constructed by MM. Schlossmacher and Ferreux. The ordinary central disk is replaced by a perforated tube on the generator, leaving the hot air escape on the products of combustion.

The lamp Peignet-Changeur, called automotrice, remedies the general fault of the petroleum lamps, the lowering of the level of the liquid in the reservoir in proportion to the consumption, by a mechanism, force pump, etc., which rises like that of the ordinary Moderator lamp. It must be remembered that this improvement, which is both complicated and expensive, takes from the petroleum its simplicity, which was one of its principal advantages, and that by having the large reservoirs placed near the burner itself it is possible to obtain an operation which is satisfactory to the practical and normal conditions of the lighting duration of a lamp.

Next to the progress made by the petroleum lamps, which we have just reviewed, we should notice also, as having contributed greatly to the successive development of these lamps in the later years, the product given to the trade by the petroleum refiners.

Crude petroleum is a mixture, in proportions essentially variable, of hydrocarbons which differ one from the other by their gaseous liquid or states at ordinary temperature; by their degrees of inflammability; their densities; their points of ebullition, etc. The systematic use of heat and cold has permitted the isolation of each of the elements, and the refining industry, which has considerably developed in France, has been able by fractional distillations to separate and gather the commercial products which unite the qualities strictly wanted. For light, for instance, it has been possible to obtain white petroleum, not emitting, under a precise temperature of 50° to 60°, for instance, vapors susceptible of ignition when coming in contact with an inflammable body. These products are often sold under special names, such as luciline, securitas, oriflamme, etc.

Outside of the petroleum lamp proper, there exists also the vapor lamps, utilizing precisely the most volatile parts of the petroleum obtained in the distillation of the crude product. These lamps are susceptible of giving normally but small intensities. The well of these lamps should be furnished with a spongy body, sponge, wool waste, etc., which absorbs the essence and feeds the wick by contact. If this precaution is well observed and the lamp well constructed, the danger is suppressed, but it is necessary to take great care in handling a liquid so volatile.

This lamp is of American origin (Chamberlain patent, 1855), but it was not until about 1865 or 1866 that it was really known in France, especially in the country; that is to say, where economy is practiced and where light of great power is not necessary. This lamp replaces quite frequently the candle or resin light.

To give an idea of the importance of the manufacture of these lamps, the cost of which for the plainest lamp varies from 0·50 to 1 fr., it is estimated that more than 500,000 lamps are delivered each year by the French manufacturers. There is a tendency, however, to substitute the petroleum lamp for this.

The principal firms exhibiting these lamps were Ristelhueber, Boisson, Legrand, Besnard, Pigeon, etc. The lamp Pigeon, much used, is of copper, the burner being interiorly lined with felt to prevent evaporation.

Finally, we will note the vapor lamps imitating gas. This result is obtained by closing the extremity of the liquid burner, and piercing several lateral holes of 0·1 millimeter in diameter. Vaporizing under the action of the heat, and by means of the small holes, the inflammable vapors rise, imitating a gaseous current.

All the oil lamps, the advantages of which we have just reviewed, present a general fault. They require a wick and an alimented reservoir; in a word, it is necessary with oil lamps to "make the lamp," which is not required with gas or electricity.

We will close this reference to the mineral oils for lighting by mentioning the heavy oil lighting apparatus, which were shown in operation at the Exposition, near the Petroleum Pavilion, namely: the Lucigen and Wells lights, lights that are essentially industrial and specially used for outdoor work and in making street improvements and work of a kindred character where transient means of lighting have to be improvised.

The Lucigen burns the heavy oils of tar, petroleum, etc., pulverized by a compressed current of air. The flame has a large surface: 0·10 m. in diameter and 0·40 m. to 0·40 m. in height, with the pressures used. This question of surface plays an important role; the hollow shadows, like those of the electric light, do not exist; the intensity is considerable, about 200 carcels, and the power necessary for operating a burner of 200 carcels is but a few kilogramme-meters.

The Wells light produces about the same effect. It does not require motive power.

These systems occasionally replace with advantage the electric light for improvised lighting. They are extremely simple, movable, easily installed anywhere and economical. The Lucigen light was used while the Forth Bridge was being constructed.

(3) LIGHTING BY GAS.

In 1878, the following figures were obtained by M. Schmitz:

Division, by Groups, of the Cities Lighted.	Number of Cities per Group.	Total Population of Each Group.
2,000 inhabitants or less..... ...	60	84,539
2,000 to 4,000 inhabitants......	171	522,332
4,000 " 6,000 "	134	656,580
6,000 " 8,000 "	85	580,233
8,000 " 20,000 "	164	2,087,165
20,000 " 40,000 "	41	1,132,408
40,000 " 80,000 "	21	1,181,726
80,000 " 200,000 "	8	1,039,513
200,000 inhabitants and above.....	3	2,658,938
Total	687	9,943,434

With new elements, we have been able to give the following census for 1889:

Division, by Groups, of the Cities Lighted.	Number of Cities per Group.	Total Population of Each Group.
2,000 inhabitants or less........	143	197,957
2,000 to 4,000 inhabitants......	276	822,933
4,000 " 6,000 "	196	951,695
6,000 " 8,000 "	126	872,079
8,000 " 20,000 "	187	2,330,095
20,000 " 40,000 "	59	1,550,943
40,000 " 80,000 "	28	1,590,873
80,000 " 200,000 "	9	1,078,973
200,000 " 500,000 "	3	1,018,655
500,000 " inhabitants and above..	1	2,344,550
Total..........................	1,028	12,758,753

The comparison of these two tables will show the progress made during the years considered.

Therefore, the number of towns lighted by gas, 687 in 1878, 1,028 in 1889, an addition of 341, or nearly 50 per cent., and the increase, as we have shown above, especially in towns of less than 8,000 inhabitants, has been:

For cities of 2,000 or less inhabitants......		83
" " " 2,000 to 4,000	"	105
" " " 4,000 " 6,000	"	62
" " " 6,000 " 8,000	"	41

As to the population lighted by gas, the increase was nearly 30 per cent.; the population being 9,943,000 inhabitants in 1878 and 12,758,000 in 1889; this represents, however, but about one-third of the total population of France, which was 38,218,000 inhabitants, according to the last census. The results obtained are easily explained by the great number of small towns in France, 33,372 out of 36,121 having a population of less than 2,000 inhabitants.

The following table shows, in each group, the towns lighted or not by gas:

Division by Groups.—(*Population.*)	Cities and Towns Lighted.		Cities and Towns not Lighted.		Total.	
	No.	Population.	No.	Population.	No.	Population.
2,000 inhabitants or less..............	143	197,957	33·229	19,983,710	33·372	20,181,667
2,000 to 4,000 inhabitants.	276	822,933	1·662	4,437,455	1·938	5,260,380
4,000 " 6,000 "	196	951,695	168	791,701	364	1,743,396
6,000 " 8,000 "	126	872,079	27	180,825	153	1,052,904
8,000 " 20,000 "	187	2,330,095	7	66,459	194	2,396,554
20,000 " 40,000 "	59	1,550,943	......	....	59	1,550,943
40,000 " 80,000 "	28	1,590,873	......	....	28	1,590,873
80,000 " 200,000 "	9	1,078,973	......	....	9	1,078,973
200,000 " 500,000 "	3	1,018,655	......	....	3	1,018,655
500,000 and more "	1	2,344,550	......	....	1	2,344,550
Totals......	1,028	12,758,753	35·093	25,460,150	36·121	38,218,903

Heating by Petroleum.—Although the general question of heating is discussed in another part of the Report of Class 27, we shall say a few words concerning the use of petroleum for heating.

The use of the domestic petroleum furnaces or stoves has greatly increased since the last Exposition, quite a number being in use about 1876, but it was not until after 1878 that they were commonly used, and the annual manufacture in France, estimated at 20,000 furnaces in 1878, increased to 60,000 after that date.

There is distinguished in the petroleum stoves, as in the lamps, using the flat burner (Besnard, Boisson, Robert, Rochester of New York, etc.), and some using the round burner (Ristilhueber, Legrand, Boisson, etc.) stoves known under the names of Universal, Vitesse, Accelere, Rapide, etc.

There exist also the vapor stoves, which burn without wicks (Desvignes of Bordeaux); the reservoir is charged above the point of combustion, brought by a metallic tube, a disposition which does not appear to unite the conditions of security desired. It must be remembered that the cost of the vapor for the bringing a liter of water to a point of ebullition is more than that of petroleum doing the same operation.

However, the petroleum stove is used more and more in the numerous towns of France wherein gas has not yet penetrated, and no less than 400,000 can be estimated as the number actually in use in France.

The application of petroleum for the heating of houses is not desirable, as it is almost impossible to prevent an odor which renders its use disagreeable.

All of the chief towns of the department, with one exception, that of Mende, are lighted by gas; 55 districts out of 275 not being so lighted.

The march of progress of the gas industry has been constant, notwithstanding the introduction of electricity at the beginning of the period considered (1878). From 1878 to 1878 the average annual increase was less than 20,000,000 cubic meters, for France entire. From 1878 to 1888 the increase was 235,000,000 cubic meters, being an average annually of 23,500,000 cubic meters. In fact, this average increase would be 29,000,000 if the last three years are taken into consideration.

Here is the confirmation of the statement made in the first part of this report: the parallel development of the lighting industries and the increase without limit of the needs of artificial lighting.

At the preceding Universal Exposition in 1878 it was not possible to give sensible modifications in gas lighting apparatus, and since investigations made previous to 1860 by MM. Audouin and Berard, under the supervision of MM. Dumas and Regnault, of the burners used and the best conditions for combustion (investigations which ended about 1861 in establishing a regular burner for the cities, and procuring notable economies in gas consumption), it can be said that gas burners have received little modification.

At the Exposition of 1878 there was but one intensive burner with triple crown giving an intensity of several carcels, and this was exhibited by MM. Sugg, of London.

COMPARATIVE SIZES OF DROP SHOT.

Manufactured in the United States by leading Manufacturers.

Merchants Shot Tower Co., New York.		Tatham & Bros., New York.		New York Lead Co., New York.		The Leroy Shot & Lead Mfg. Co., New York.		Thos. W. Sparks, Philadelphia, Pa.		St. Louis Shot Tower Co., St. Louis, Mo.		Dubuque Shot Mfg. Co., Dubuque, Iowa.		Shelby Smelt'g and Lead Co., San Francisco, Cal.		Chicago Shot Tower Co., Chicago, Ill.	
Sizes.	No. Pellets to oz.	Sizes.	No. Pellets to oz.	Sizes.	No. Pellets to oz.	Sizes.	No. Pellets to oz.	Sizes.	No. Pellets to oz.	Sizes.	No. Pellets to oz.	Sizes.	No. Pellets to oz.	Sizes.	No. Pellets to oz.	Sizes.	No. Pellets to oz.
TTTT	22	FF	24			TTTT	24										
TTT	26	E	27			TTT	27	F	22	000	29	000	27			000	27
TT	30	TT	31	TT	32	TT	32	TT	36	00	32	00	33			00	33
T	34	T	36	T	38	T	38	T	41	0	40	0	38			0	38
BBB	39	BBB	42	BBB	44	BBB	44	BBB	48	BBB	46	BBB	46	BBB	46	BBB	46
BB	45	BB	50	BB	49	BB	49	BB	55	BB	53	BB	53	BB	55	BB	53
B	58	B	59	B	58	B	58	B	63	B	63	B	62	B	68	B	62
1	60	1	71	1	69	1	69	1	80	1	79	1	75	1	79	1	75
2	77	2	86	2	82	2	82	2	90	2	98	2	92	2	89	2	92
3	94	3	106	3	98	3	98	3	118	3	116	3	118	3	119	3	118
4	115	4	132	4	121	4	121	4	130	4	167	4	146	4	134	4	146
5	140	5	168	5	149	5	166	5	182	5	181	5	172	5	170	5	172
6	180	6	218	6	209	6	209	6	245	6	252	6	246	6	215	6	246
7	225	7	291	7	278	7	278	7	305	7	306	7	323	7	303	7	323
8	365	8	390	8	375	8	375	8	426	8	426	8	434	8	420	8	434
9	610	9	568	9	560	9	560	9	615	9	584	9	596	9	592	9	596
10	1130	10	848	10	822	10	822	10	950	10	981	10	854	10	874	10	854
11	2200	11	1346	11	982	11	982	11	1660	11	1603	11	1414	11	1404	11	1414
12	3200	12	2336	12	1078	12	1778	12	3316	12	2305	12	2400	12	2080	12	2400
13	12200							Dust.	5910								

The Exposition of 1889, on the contrary, showed important changes and innovations.

Previous to 1889 the burners of more than 1 to 3 carcels, having minimum consumption of 100 to 125 liters, were but little known. There are in use to-day burners of 20, 30, and 50 carcels, practically consuming 50, 40, and 30 liters per carcel.

Therefore, there is a possibility of obtaining—the gas—intensities unknown in the past, with an economy in consumption of more than 50 per cent. Such was the progress made since the last exposition, and of which we shall now speak.

To begin, we will recall that the unity of light to which the luminous intensities are compared so far is the carcel; that is to say, the brightness of a Carcel lamp burning 42 grammes of purified colza oil per hour in the Bengel burner, as defined in the instructions of Dumas and Regnault.

The International Conference in 1884 adopted, as a unit of light, a small portion or sample of platinum; that is, the quantity of light emitted in a normal direction by a square centimeter of platinum melted to the temperature of solidification.

Finally, the International Congress of 1889 decided to take, as a practical unit, under the name of decimal candle, the twentieth part of the absolute standard of light defined by the International Conference of 1884.

The standard of platinum is worth 2·08 carcels. The following table will show these unities:

Name.	Platinum.	Carcel.	Decimal Candle.
Platinum..................	1·00	2·08	20·00
Carcel	0·48	1·00	9·60
Decimal candle	0·05	0·104	1·00

The decimal candle thus defined is found to be very similar to the English candle standard, constantly used to this day in electrical matters and to the tenth of the carcel; the respective transformation of these unities can be easily made by the preceding table.

We will now examine the principal types of new gas burners which were shown at the exposition of Class 27, its annex and at the gas pavilion.

All of the new lamps of which we have spoken were classified as:

(1) High power open air lamps.

(2) Regenerative lamps; that is, lamps in which the air aiding combustion is previously heated by the recuperation of the heat taken from the products of the combustion.

(3) Incandescent gas lamps; that is, lamps in which the gas, acting by its calorific effect, carries to incandescence a solid material which becomes a luminous center.

(4) Carbureted gas lamps; that is, lamps in which the lighting power of the gas is increased by the addition of rich hydrocarbons.

(1) *High Power Open Air Lamps.*—In a general manner it can be said that until the Exposition of 1878, the need of greater power of light did not seem to make itself felt, lighting being limited to the Argand and open air burners.

As an interior burner for extensive lighting, the Sun burner, of English manufacture, can be well considered. It is composed of a large number of small Manchester burners (sometimes more than one hundred) disposed in such a way as to have the flames horizontal, and placed side by side under the same cupola, communicating with the exterior air. This burner, used in large stores, gives a bright light and assures at the same time good ventilation, though economical in the consumption of gas.

For public lighting, or for improving light in certain places, for instance, it was customary to install candelabra with several lanterns (such as the candelabra of five lanterns in the Place du Carrousel, etc.), sometimes putting two burners in the one lantern.

The introduction of the electric candle Jablochkoff in 1876, its application at the Louvre in 1877, and especially its adoption as an experiment on the Place, then on the Avenue de l'Opera, marked the point of evolution in public lighting, and soon afterward in interior lighting.

The gas industry was until then inspired with the principle of Lavoisier: "The object which should be considered in lighting a large city," said the illustrious savant, "is not to suspend a small number of lanterns which consume much, but, on the contrary, a large number which consume little." But, seeing that the taste of the public leaned toward the intense luminous foyers, the industry began furnishing these to respond, as it were, to a demand which had not been satisfied, and it is curious enough to remark that at that period electric lighting, which had, as a starting point, powerful foyers, was seeking a smaller light (which was not found until about 1880 by the introduction of the incandescent lamp), whereas, the gas manufacturers were making efforts in the opposite direction.

From the time the public appeared to favor burners of great intensity, the inventors set to work and gave full scope to such burners.

By the intensity of the light produced by the gas, increasing according to the law or rule applicable to all light (that is, furnishing an intensity so much the more per unity of volume consumed as the consumption of the burner is greater), a better return is obtained; thus, while the burner of the Ville de Paris type consumes 105 liters to give the carcel high power, burners of the same kind, and especially those manufactured previous to 1878 by Sugg, of London, gave 12 to 13 carcels for 900 liters of gas, being 70 to 80 liters per carcel; or, otherwise said, the luminous return increases if the consumption of gas is increased in the unity of time, the two burners of 60 liters put close together produce less light than a single burner of 120 liters. These are the considerations which guide in the construction of the different models of connected burners, etc.

The first high power city burner practically used, and the best known, was that called the 4 Septembre, which the Parisian company put in operation about 1878 in the street of that name, near the Avenue de l'Opera, for the purpose of comparison with the electric lamps of Jablochkoff, which had just been installed.

The 4 Septembre burner is composed of 6 batwing burners with a 0·6 millimeter slit, consuming each 233 liters per hour (being a total of 1,400 liters) and disposed on a circle about 0·16 m. in diameter. To give a stiffness to the flames, there are placed under the burners two concentric grooves in crystal, which form a chimney; this well known burner works with remarkable regularity. Besides presenting decorative effects, it gives for the consumption above indicated of 1,400 liters an average intensity of 13 carcels, being 105 liters per carcel, which is more economical than the ordinary burners of 140 liters giving 1 carcel, being 127 liters per carcel.

The comparison between the high power gas lighting of the Rue du 4 Septembre and the lighting in the Avenue del l'Opera by the Jablochkoff is as follows:

Gas (Rue du 4 Septembre).

Surface ......6,624 square meters (552 × 12 m.)
Carcels ....80 burners × 13 carcels = 1,040 C.
Being 0·15 carcel per square meter.

Lamps Jablochkoff (Avenue de l'Opera).

Surface. .11,200 square meters (700 m. × 16 m.)
Carcels. .32 foyers × 20 carcels = 20 carcels = 640 carcels.
Being 0·05 carcel per square meter.

The intensity obtained with the gas was considerably more; it even appeared, for the period, so considerable that, at the end of a certain time of trial, the number of lanterns in the Rue du 4 Septembre was diminished about one-half.

While as to the consumption the gas also had the advantage; the hourly cost for the city of Paris, which pays for its gas 0·15 fr. (to be more exact 0·13 fr., deducting the 2 centimes paid for tax), was 80 burners × 1 cm. 400 × 0·13 fr. = 14·56 fr.

The cost of the lamps Jablochkoff was 32 foyers × 0·60 fr. = 19·20 fr. for a much lower intensity, as shown above.

The advantage then remained with the gas, and the Jablochkoff lighting disappeared in the Avenue de l'Opera in 1882, after having lowered the price of the lamp to 0·30 fr. per hour in order to sustain the comparison—a price which caused a loss to the society of 100 francs per day.

Before the success of the 4 Septembre burner, the Parisian company introduced another type, somewhat similar, of 875 liters, and about the end of 1878 the application of these burners in the different highways was regulated as follows, from the report of December, 1878, presented by M. Cernesson, in the name of the Commission of Municipal Council:

Name.	New.			Old.		
	Number of Lamps.	Consumption per Lamp, per Hour.	Total Consumption.	Number of Lamps.	Consumption per Lamp, per Hour.	Total Consumption.
Rue du 4 Septembre............	80	cm. 1·400	cm. 112,000	30	cm. 0·140	cm. 4,200
Place du Chateau d'Eau..........	19 62	1·400 0·875	26,600 54,230	77	0·140	10,780
Total per hour..	—	—	192,850	—	—	14,980

The yearly consumption, according to these figures (counting 2,073 hours to the year), would show:

2,073 × 192,850 = 399,788 cubic meters.
2,073 × 14,980 = 31,053 cubic meters.

As shown, the quantity of light was more than tenfold.

This table is of a nature to show all that would be demanded of the gas for public lighting in the presence of the way opened by the electric light. There was at Paris (inside the fortifications) in 1882, 299 burners of 875 liters and 466 burners of 1,400 liters; in 1888, the number of burners of 1,400 liters increased to 1,126, and that of the burners of 875 liters increased to 379, without taking account of the other types, of which we shall speak further on.

However, this same type served for the construction of an apparatus with a power considerably greater, which was shown at the exposition; the 4 burners consuming 4,500 liters per hour, installed in one of the highways leading to the gas pavilion. There were 18 burners disclosed on two concentric crowns, one with 12 and the other with 6 burners. The intensity was about 80 carcels, having a consumption of 56 liters per carcel; the light was 5·30 m. above the ground.

As we have said, the inventors found themselves encouraged in the way of developing such burners, and it was for this reason that M. Ellisen presented a series, either open air burners or with glass chimneys, to the Congress of the Technical Society of the Gas Industry, which held a meeting at Lille, in 1879, among which we will mention:

Sugg burner, of 1 or 2 crowns, with glass chimney.
Giroud burner, with glass chimney.
Mallet burner, open air.
Coze burner, open air.
Gautier burner, with chimney placed at a distance above burner.
Wighan burner, with chimney placed at a distance above burner.

All these burners tried to emulate the 4 Septembre burner, but without success. The burners with special chimneys, which had been much used in London, gave place to burners with flat flames of 3 and 5 branches, constructed by the two principal firms of Sugg and Bray, and were placed in large lanterns. These manufacturers presented at the Exposition of the Crystal Palace in 1882 monumental lanterns containing 24 flat flames, and giving 60 carcels, but these were especially for the exposition, and the current types were generally of 3 or 5 flat flames (Whitehall type, etc.) with lanterns of more acceptable forms and dimensions.

As to the types with chimneys, the names of which are many, these were reserved for interior lighting.

We will also add, in closing the subject of high power burners without regeneration, the Krausse lantern, much used in Switzerland and in Germany, and of which a type of 3 flames was installed near the gas pavilion at the exposition; these resemble the Sugg lanterns, and present, as a lighting apparatus, a bouquet of 3 branches, each branch provided with a burner; each burner is composed of two flames in joined steatite, with a 0·3 slit, disposed in such a fashion that the 2 flames almost unite. The adoption of the joined burners is for the reason that burners of small consumption or delivery are used, and also to avoid a soft flame. The reflector of these lanterns is particularly well disposed, and its effect is certainly satisfactory. Repeated experiments have given as their lighting power 4 carcels 33, with a consumption of 495 liters per hour, being 113 liters per carcel.

These lanterns are used in a large number of cities, among which are: Geneva, Bale, Munich, Amsterdam, Florence, etc.

We will now take up the question of regenerative burners for public lighting.

(2) *Regenerative Burners.*—To a Frenchman, Chaussenot, is due the honor of having, more than half a century ago, revived the interest pertaining to the raising of the temperature of air aiding the combustion of gas in the burner, in an increasing point of view of the luminous intensity produced.

It was not long after, in 1879, that Frederick Siemens, of Dresden, utilized the powerful means of regeneration for heating the air, as already applied in the great industries for heating, rendering practical the idea of Chaussenot and introducing the high power regenerative burners so much in use now with different improved types.

We will also recall the name of Chaussenot, who obtained, in 1836, a prize of 2,000 francs given by the Society of Encouragement, for his lamp "uniting the most efficacious means for increasing the lighting power of flames produced by the combustion of illuminating gas," following a report proving that it could realize an economy of 30 per cent. in the consumption of gas.

The Chaussenot burner was composed of 2 concentric chimneys. The exterior one was closed at the bottom, the air aiding the combustion reaching the flame only when passing through the upper part between the two chimneys, where the temperature is considerably raised.

Its complications and its fragility did not permit it to be practically used; besides, the need of intense lighting had not as yet made itself felt, but the principle of the hot air burner was set.

It is known that gas is not an illuminant by itself, and that in a general manner the flames owe their lighting power to the incandescence of solid particles which they hold in suspension. Those which render coal gas an illuminant, in particular, are the particles of carbon proceeding from the dissociation

at high temperature of the hydrocarbons which enter into its composition.

It is also known that the quantity of light emitted by a solid incandescent body increases rapidly with the temperature. Becquerel, having endeavored to establish a law binding the temperature of incandescent bodies and the luminous intensities, arrived at the exponential formula

$$I = a\,[e^{b}\,(-\theta) - 1]$$

in which

I represents the luminous intensity.

T represents the temperature of the bodies.

θ represents the temperature at which the first luminous rays are emitted.

e represents the base of the logarithm.

a and *b* represent the constant coefficients for a similar experiment.

In these conditions, the luminous intensities increase in proportion as the temperature is raised with extreme rapidity.

This formula was not applicable to very high temperatures, and the works of Preece showed that the luminous intensities rose less quickly than is indicated in the formula of Becquerel. However, the rapid increase of the luminous intensity with the temperature is an established fact, and all the importance of increasing the temperature is well understood; this is what Chaussenot obtained in previously heating the air necessary for combustion. In fact, in the combustion, the inert gas which forms more than three-fourths of the air absorbs a large part of the free heat, and thereby prevents the flame from obtaining a high temperature; but, if the air is previously heated at a high temperature, it carries by itself a quantity of heat capable of compensating, in a certain measure, for the heat so absorbed, and restores to the flame the high temperature which it would have attained with the oxygen nearly pure.

(*To be continued.*)

TOY PARACHUTES.

THE small parachutes of thin paper whose edges were connected by threads with a cork that simulated

NEW TOY PARACHUTE.

the car had the inconvenience of not being able to operate unless they were allowed to fall from an elevated point, say from an upper window of a house. The resistance of the air caused the parachute to open, and the threads attached to the cork kept the lower part concave and prevented it from turning up.

Quite an ingenious variant of this toy was brought out a few years ago. The parachute, which was made of a light fabric, was folded in a small lacquered cardboard box open at its upper part and having the form of a car. The apparatus was projected from the ground to as great a height as the child could throw it, and the air, traversing a small aperture in the bottom of the car, forced the parachute to spread out. The apparatus then descended slowly with the little figure that simulated the aeronaut and that was previously concealed in the box under the folds of the fabric. The high price of the apparatus and the difficulty that children had in throwing it far enough prevented its dissemination among young people.

We now have a parachute of a new system that has been named the *Phenix Parisien*, and which well merits this slightly pompous title, owing to the method of throwing it devised by its inventor.

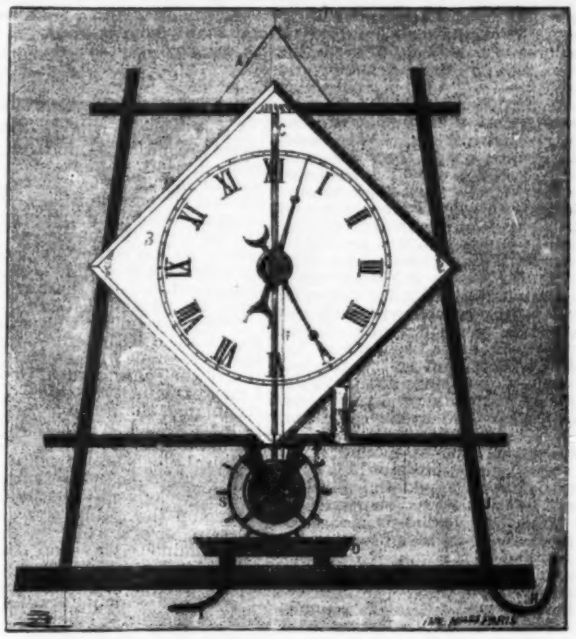
Imagine an umbrella in which the ribs are replaced by threads that are connected with a ring that slides along the handle. The latter is a slender wooden rod, to the extremity of which is fixed the center of the parachute. The other extremity carries a small bone button provided with a notch. The folded parachute is slid into a cardboard cylinder carrying at one of its extremites a strong rubber band fixed to the sides of the opening of the tube. For projecting the parachute, we proceed as in shooting with a bow, in which the arrow is here the rod of the parachute, and the string the rubber band. The tube containing the parachute being vertical, the bone button is pulled after the rubber has been placed in the notch. Then the button is suddenly set free, and the rubber, in flying back, projects the rod to a height of 12 or 15 feet.

The weight of the rod assures its verticalness, and the parachute opens as soon as the descent begins. The tension of the threads is maintained by the weight of the ring that slides along the rod. If it is blowing, turn the back to the wind in order to project the apparatus, the tube being slightly inclined forward. The wind will contribute toward causing the parachute to open and keeping it in the air longer. I may state, even, that among the parachutes of this kind that I have tried, one of them, caught by an ascending current of air, alighted gently upon the balcony of a fifth story, to the great delight of those who, for the first time perhaps, saw a parachute operate like a balloon.

A contest of a new kind might be organized at country fairs, in which a parachute of a different color would be given to each contestant. At a given signal all the parachutes would be projected together, and the prize would belong to the one that remained in the air longest.—*A. Good, in La Nature.*

HYDRAULIC CLOCK.

LIKE the floral clock that we have already described, the clock figured herewith is actuated by hydraulic power, but for the operation of this new model, of which the mechanism is very simple, the power necessary is exceedingly feeble.



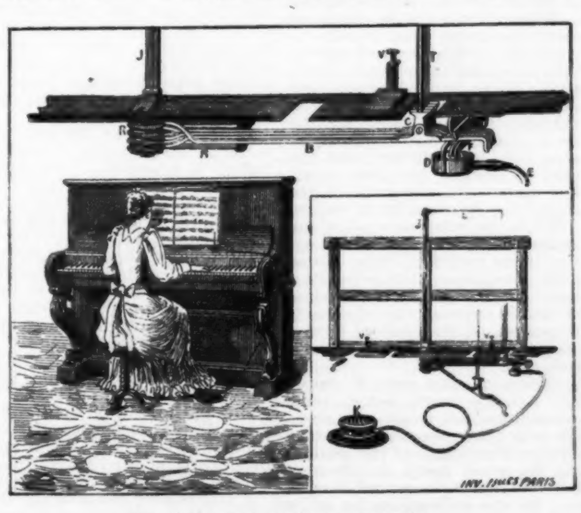
HYDRAULIC CLOCK.

Upon the axis of the escapement wheel is fixed a paddle wheel, S, upon which fall drops of water from a vessel, E, supplied by a conduit, H, that leads the liquid from a reservoir that may be located in any place whatever. The motion of the paddle wheel produced by the fall of the drops of water keeps up the motion of the pendulum. The escapement wheel carries an eccentric pin, which, at every revolution of the wheel, raises a detent lever that it afterward sets free. In its descent, this lever, through the rod, F, carries along the hands of the dial, B, in making them move forward by one minute, a period corresponding to one revolution of the wheel.

The pendulum rod is figured at C, and its bob at G. The water that has actuated the wheels falls into a small trough, D, and flows out through the tube, T.—*Les Inventions Nouvelles.*

PNEUMATIC LEAF TURNER.

THE apparatus represented herewith is designed for turning the leaves of a book of music without the necessity of the player using his hands. The apparatus is here shown mounted upon a piano. To this effect, it suffices to remove the strip of wood forming a ledge at the bottom of the music stand and to replace it by the base of the leaf turner, which is fixed by means of small binding screws, *v*, *v*, easily tightened by hand. The holder, J, the foot of which engages in a recess formed in the base, is then put in place. A pedal, K, placed upon the floor, is connected with the mechanism by means of a rubber tube, E, that runs along the bracket of the piano and back of the candles. In order to use the apparatus, the book of music is introduced by its center under the holder and the rod, L, previously raised, is then lowered. Then the music book is closed in turning it to the left and placing the cover and the leaves that it is not desired to turn under the spring, H. Afterward each leaf is introduced in succession between two needles mounted upon arms, B, capable of revolving around an axis provided with a spiral spring, R, that tends to press the arm from right to left. Those arms with the leaves of music are pressed down one by one toward the right, where they are held by a hook with an anchor escapement, allowing but a single arm to disengage itself at each oscillation. The pedal, K, contains a rubber bulb with an air hole and springs that keep it inflated. When the pedal is acted upon, the air is compressed, flows through the rubber tube, E, and raises a rubber diaphragm placed at D to the right of the leaf turner and under the hook that holds the arms, B. The hook rises under the pressure transmitted through the intermedium of the diaphragm, and, pulled by the spring, the disengaged arm flies back and carries along the leaf inserted between its needles, T. This operation is peformed very rapidly and noiselessly.



PNEUMATIC LEAF TURNER.

The apparatus is easily adapted to every kind of wooden music stand.—*Les Inventions Nouvelles.*

HYPODERMOKLYSIS.

DR. MAX HILDEBRAND, of San Francisco, Cal., has contributed a paper to the Proceedings of the California Academy of Medicine, which has been published in the *Occidental Medical Times* for June, 1892.

Hypodermoklysis consists, as the term implies, in the introduction of fluid under the skin, in order to wash out the system through the natural channels of circulation. In the experiments that were made by Dastre and Loye, about three years ago, on dogs and rabbits, a 0·7 per cent. solution of chloride of sodium was employed, and injected directly into the veins of the animals. Four times the amount of the normal quantity of the blood may be infused in this manner without any danger to the life of the animal on which the operation is performed.

In the first place, the most remarkable fact may be mentioned that the blood pressure, which could reasonably be expected to increase after the infusion, from general plethora, is by no means higher than before. The diuretic effect of the infusion becomes apparent about two or three hours afterward. The infusion of this so-called physiological solution may

be regulated in such a manner that within fifteen minutes for every pound weight of the animal's body one drachm of the solution is passed into the blood current. Thus, for an ordinary dog, weighing about twenty pounds, the maximum harmless quantity of salt water infused into his system would be about two drachms per minute, and, if this ratio is kept up, the infusion may last for hours, with the result that the same quantity of urine is discharged as salt water is passed into the system. If, however, the pressure of the salt water injection—that is, the rate of the current—is increased above these figures, the accumulation of water in the system proves fatal to the animal, because the kidneys cannot evacuate it as speedily as it is injected. The infusion takes place in such a manner that, if a certain quantity of the solution has been deposited within the walls of the blood vessels and within the tissues of the body, diuresis sets in, and the quantities of the injected and discharged fluids are perfectly balanced. If at this moment any more solution was injected, it would be exactly as if fluid were passed into a cask already full, that of necessity must run over.

While infusion is going on, the urine of the animal becomes gradually paler, and diminishes both in specific gravity and in its mineral constituents until it is almost similar to the fluid injected. In this way the tissues of the body are, as it were, washed out, and more urine is carried off than would have been possible without the infusion. It may be stated here that albumen does not appear in the urine during the process. It must, however, be remembered that the infusion of the physiological solution into the veins of animals is only a harmless operation provided the heart is perfectly healthy, otherwise the increased tension of the right ventricle may prove a source of serious danger to the animal. Even if we leave this circumstance out of account for a moment, it is proved by the experiments of Roux and Yersin (*Annales de l'Institut Pasteur*, 1889, "Contributions a l'Etude de la Diphtherie") that the treatment by means of salt water infusion of animals that were poisoned with different bacterial products has given very bad results. Under these circumstances it would have been out of the question to use the direct infusion of salt water into the veins in the treatment of diseases in man. It was necessary to find a method that could produce the beneficial effects of the infusion, and at the same time avoid its dangers.

The merit of the discovery of this new method is due to Cantani, who first conceived the brilliant idea of injecting the physiological solution hypodermically, and named it "hypodermoklysis." It was employed by him in two different conditions—exhaustion after severe losses of blood and in cholera. His purpose was to replace the loss of water, and in this way to overcome the drying up of the tissues. But this is not all. We know that a great many diseases, the nature and the origin of which were recently a sealed book, are produced either by the excretions of microbes living in our bodies or by the physiological excretions of the body itself. The investigations of Brieger leave no doubt that both yield a variety of highly poisonous substances, which are either alkaloid, produced by decompositions, and called ptomaines or toxines, or derivatives of pathogenic bacteria, and called toxalbumines. Toxines and toxalbumines, when brought into the circulation, give rise to extremely dangerous intoxications. It has been proved by the investigations of Bouchard, Roux, and Yersin that in many diseases, especially those combined with fever, the poisonous substances, which circulate in the blood, leave the body by way of the kidneys, and it is a well known fact that in different morbid conditions—for instance, in uræmia, typhoid fever, cholera, tetanus, etc.—the reappearance of a copious discharge of urine is considered a sign of favorable prognosis.

The introduction of saline infusions in the regular treatment of diseases has opened a new and extensive field for medical action. The results that have been published by careful observers of different nations have contributed to establishing this method as a most powerful remedy in cases where formerly the physician was compelled to retreat with resignation from the field of action. The method of performing the infusion is very simple. A glass vessel, containing about thirty to forty ounces, is filled with a sterilized solution of 7 parts chloride of sodium and 1,000 parts of water (about three and a half grains to the ounce). The temperature should be about 110° F. A glass siphon leads through a tight stopper from the vessel to an India rubber tube ending in a large sized trocar. A glass pipe, filled at the upper end with sterilized cotton, leads to the bottom of the vessel for the purpose of admitting the necessary air. It is unnecessary to add that the utmost care should be taken that all parts of the apparatus be sterilized. The best place for the injection is the abdomen. As soon as the trocar is pushed through the skin into the cellular tissue the saline solution is injected by holding the glass vessel about four or five feet above the abdomen of the patient. The time required for infusing thirty ounces is about five minutes. While the infusion is going on, a tumor is gradually formed, the contents of which are absorbed by the cellular tissue in about three hours. While it is true that the formation of this tumor is rather painful, on account of the tension of the skin, it must be remembered that in the majority of cases in which the operation is performed the patient is in a semi-conscious condition, and in the remainder it disappears in two or three hours.

The effect of the operation in some cases is simply surprising. Where, only a few minutes before, pulse and respiration had ceased, and all hope was abandoned, a perfect change may take place, and a rather abrupt inspiration indicates the return of the patient to life. In other cases the good result is apparent more slowly, and is often denoted by increased diuresis and lower temperature. As the indications for saline infusions are so manifold that their enumeration would far exceed the limits of this paper, I will only mention the most important.

In the first place, saline infusions have proved successful in cases where severe loss of blood had occurred, and, as has already been mentioned, in cholera. It has been employed by Sahli, of Berne, in cases of uræmia and of typhoid fever, with excellent results. He says that, apart from the diuretic effect of the infusions and the washing out of the system, he is of opinion that great stress should be laid upon the fact that the specific poisons in the tissues and in the blood are diluted by the infusion. He also points out the importance of the possibility, in typhoid fever, of introducing sufficient quantities of water into the body, notwithstanding the presence of diarrhœa and prostration of the digestive organs, and thus counteracting the drying up of the tissues. Besides these cases, hypodermoklysis has been successfully employed in the following conditions: Septic blood poisoning, diabetic coma, gastric or intestinal ulcers, and anæmia; and Sahli recommends it very strongly in cholera infantum, although he has not tried it himself in his disease.

From his own experience, Hildebrand can very strongly recommend it in asphyxia from chloroform. In two cases under his observation it acted promptly, after electricity and artificial respiration had failed. He would, however, unhesitatingly employ it, as the only means of saving life in intoxication from alcohol, morphine, carbonic oxide, and in all apparently hopeless cases of snake bite. Hildebrand is perfectly certain that many lives would be saved in this way. Of course, time and careful observation alone will show whether hypodermoklysis is as powerful and expedient a remedy as, judging from present standpoints, could reasonably be expected.

OUR SENSE OF COLOR.*

By Prof. WILLIAM RUTHERFORD, M.D.

I MAY premise that our conceptions of the outer world are entirely founded on the experience gathered from our sensory impressions. Through our organs of sensation, mechanical, chemical, and radiant energies impress our consciousness. The manner in which the physical agents stimulate the peripheral sense organs, the nature of the movement transmitted through our nerves to the centers for sensation in the brain, the manner in which different qualities of sensation are there produced—all these are problems of endless interest to the physiologist and psychologist.

Every psychologist has acknowledged the profound significance of Johannes Muller's law of the specific energies—or, as we should rather say, the specific activities of the sense organs. To those unfamiliar with it, I may explain it by saying, that if a motor nerve be stimulated, the obvious result is muscular movement; it matters not by what form of energy the nerve is stimulated—it may be by electricity or heat, by a mechanical pinch or a chemical stimulus, the specific result is muscular contraction. In like manner, when the nerve of sight is stimulated—it may be by light falling on the retina, or by electricity, or mechanical pressure, or by cutting the nerve—the invariable result is a luminous sensation, because the impression is transmitted to cells in the center for vision in the brain, whose specific function is to produce a sense of light.

The same principle applies to the other sensory centers; when thrown into activity, they each produce a special kind of sensation. The sun's rays falling on the skin induce a sense of heat, but falling on the eye, they induce a sense of sight. In both cases the physical agent is the same; the difference of result arises from specific differences of function in the brain centers concerned in thermal and visual sense. We have no conception how it is that different kinds of sensation arise from molecular movements in the different groups of sensory cells; we are as ignorant of that as we are of the nature of consciousness itself.

The subject I propose to discuss on this occasion is not the cause of the different kinds of sensation proper to the different sense organs, but the causes of some qualities of sensation producible through one and the same sense organ.

The theory of tone sensation proposed by Helmholtz is that the ear contains an elaborate series of nerve terminals capable of responding to tones varying in pitch from sixteen vibrations to upward of 40,000 vibrations per second, and that at least one different fiber in the auditory nerve, and at least one different cell in the center for hearing, is affected by every tone of perceptibly different pitch. Although the physical difference between high and low tones is simply a difference in frequency of the sound waves, that is not supposed by Hemholtz to be the cause of the different sensations of pitch. According to his theory, the function of frequency of vibration is simply to excite by sympathy different nerve terminals in the ear. The molecular movement in all the nerve fibers is supposed to be identical, and the different sensations of pitch are ascribed to a highly specialized condition of cells in the hearing center, whereby each cell, so to speak, produces the sensation of a tone of definite pitch, which in no way depends on the frequency of incoming nerve impulses, but simply on the specific activity of the cell concerned.

In my lecture on the sense of hearing I pointed out in detail the great anatomical difficulties attending the theory in question. I endeavored to show the physical defect of a theory which does not suppose that our sensations of harmony and discord must immediately depend upon the numerical ratios of nerve vibrations transmitted from the ear to the central organ, and I offered a new theory of hearing based upon the analogy of the telephone. According to that theory, there is probably no analysis of sound in the ear; the air cells at the peripheral ends of the auditory nerve are probably affected by every audible sound, of whatever pitch. When stimulated by sound they probably produce nerve vibration, simple or compound, whose frequency, amplitude, and wave form correspond to those of the sound received. The nerve vibrations arriving in the cells of the auditory center probably induce simple sensations of tones of different pitch, or compound sensations of harmonies or discords strictly dependent on the relative frequencies of the nerve vibrations coming in through the nerve.

I cannot now recapitulate the evidence derived from anatomical, experimental, and pathological observations that give support to my theory of hearing, but I may briefly say that it is opposed to the theory of specific activities, in so far as it has been applied to explain the different qualities of sound sensation. It is, however, in strict accord with the fundamental proposition stated by Fechner,† in his great work on psychophysics, in these words: "The first, the fundamental hypothesis is that the activities in our nervous system on which the sensations of light and sound functionally depend are, not less than the light and sound themselves, to be regarded as dependent on vibratory movements." It is evident that, if we could only comprehend the nature of the molecular movement in the nerve that links the vibration of the physical agent to that in the sensory cell, we could advance toward a true theory of the physiological basis of different qualities of sensation in the different sense organs. As yet no definite answer can be given to the question, What sort of molecular movement constitutes a nerve impulse?—but in recent years our knowledge of the subject has been extended in a direction that opens up a vista of new possibilities.

A nerve impulse travels at a rate not much more than one hundred feet per second—an extremely slow speed compared with that of electricity in a wire. It has been thought to be of the nature of a chemical change sweeping along the nerve, but that hypothesis is opposed by the fact that the most delicate thermopile shows no production of heat, even when an impulse is caused to sweep repeatedly along the same nerve. Again, it is far easier to fatigue a muscle than a nerve. A living frog's nerve removed from the animal, and therefore deprived of all nutrition, can retain its excitability for nearly an hour, although subjected all the while to thirty or forty stimulations per second. An excised muscle when similarly stimulated is exhausted far sooner, because the mechanical energy entirely springs from chemical change in the muscular substance, and therefore the muscle is more easily fatigued than the nerve. The molecular motion in an excited nerve produced a momentary electric current; but that result is not peculiar to nerve. The same occurs in muscle when stimulated. Possibly the molecular movement is of the nature of a mechanical vibration: at all events, we know now that a nerve can transmit hundreds, even thousands of impulses, or let us simply say vibrations, per second. The fact is so important and significant in relation to the physiology of the sense organs that I show you an experiment to render it more intelligible. A frog's muscle has been hooked to a light lever to record its movement on a smoked cylinder. The nerve of the muscle has been laid on two electrodes connected with the secondary coil of an induction machine. In the primary circuit a vibrating reed has been introduced to serve as a key for making and breaking the circuit, and so stimulating the nerve with periodic induction shocks. If we make the reed long enough to vibrate ten times per second, ten impulses are sent through the nerve to the muscle, and ten distinct contractions produced, as shown by the wavy line upon the cylinder. If we shorten the reed so that it will vibrate say fifty times per second, the muscle is thrown into a continuous contraction and traces a smooth line on the cylinder; but if we listen to the muscle, we can hear a tone having a pitch of fifty vibrations per second, from which we know that fifty nerve impulses are entering the muscle and inducing fifty shocks of chemical discharge in the muscular substance. If we take a reed that vibrates, say 500 times per second, we hear, on listening to the muscle, a tone having the pitch of 500 vibrations. Observe, that we are not dealing with the transmission of electrical shocks along the nerve, but with the transmission of nerve impulses. By stimulating the nerve with wires of a telephone it has been shown by D'Arsonval that a nerve can transmit upward of 5,000 vibrations per second, and that the wave forms may be so perfect that the complex electrical waves produced in the telephone by the vowel sounds can be reproduced in the sound of a muscle after having been translated into nerve vibrations and transmitted along a nerve. Such experiments go far in helping us toward a comprehension of the capabilities of nerves in transmitting nerve vibrations of great frequency and complicated wave form; but although they enable us reasonably to suppose that all the fibers of the auditory nerve can transmit nerve vibrations, simple or complex, and with a frequency similar to that of all audible tones, we encounter superlative difficulty in applying such a theory to the sense of sight. In objective sound we have to deal with a comparatively simple wave motion whose frequency of vibration is not difficult to grasp even at the highest limit of audible sound—about 40,000 vibrations per second. But in objective light the frequency of vibration is so enormous—amounting to hundreds of billions per second—that every one feels the difficulty of forming any conception of the manner in which different frequencies of ether waves induce differences in color sensation.

But before passing to color sense, I wish to allude for a moment to the sense of smell. The terminals of the olfactory nerve in the nose are epithelial cells. It has been recently shown by Von Brunn* that in man and other mammals the cells have at their free ends very delicate short hairs, resembling those long known in lower vertebrates. These hairs must be the terminal structures affected by substances that induce smell, and are therefore analogous to the hairs on the terminal cells in our organ of hearing. No one ever suggested that the hairs of the auditory cells can analyze sounds by responding to particular vibrations, and I think it quite as improbable that the hairs on any particular olfactory cell respond to the molecular vibrations of any particular substance. If we follow those who have had recourse to the doctrine of specific activities to explain the production of different smells, we must suppose that at least one special epithelial cell and nerve fiber are affected by each different smelling substance. Considering how great is the variety of smells, and that their number increases with the production of new substances, it would be a somewhat serious stretch of imagination to suppose that for each new smell of a substance yet to emerge from the retort of the chemist there is in waiting a special nerve terminal in the nose. It seems to me far simpler to suppose that all the hairs of the olfactory cells are affected by every smelling substance, and that the different qualities of smell result from difference in the frequency and form of the vibrations initiated by the action of the chemical molecules on the olfactory cells and transmitted to the brain. That hypothesis was, I believe, first suggested by Prof. Ramsay,† of Bristol, in 1882,

* Opening presidential address, Section D, Biology, British Association, 1892.

† "Elemente der Psychophysik," 1860, 2d edition, 1889, part ii, p. 282.

* Von Brunn, *Archiv fur mikroskopische Anatomie*, 1892, Band [illegible].

† Ramsay, *Nature*, 1882, vol. xxvi., p. 180.

and it seems to me the only intelligible theory of smell yet offered. But it must be admitted that a theory of smell, such as that advanced by Ramsay, involves a more subtile conception of the molecular vibrations in nerve fibrils than is required in the case of hearing. It involves the conception that musk, camphor, and similar substances produce their characteristic qualities of smell by setting up nerve vibrations of different frequencies and probably of different complexities. We shall see what bearing this may have on the theory of color sense, to which I now pass.

No impressions derived from external nature yield so much calm joy to the mind as our sensation of color. Pure tones and perfect harmonies produce delightful sensations, but they are outrivaled by the color effects of a glorious sunset. Without our sense of color all nature would appear dressed in bold black and white, or indifferent gray. We would recognize, as now, the beauty of shapely forms, but they would be as the cold engraving contrasted with the brilliant canvas of Titian. The beautiful tints we so readily associate with natural objects are all of them sensations produced in our brain. Paradox though it appear, all nature is really in darkness. The radiant energy that streams from a sun is but a subtile wave motion, which produces the common effects of heat on all bodies, dead or living. It does not dispel the darkness of nature until it falls on a living eye, and produces the sense of light. Objective light is only a wave motion in an ethereal medium; subjective light is a sensation produced by molecular vibration in our nerve apparatus.

The sensory mechanism concerned in sight consists of the retina, the optic nerve, and the center for visual sensation in the occipital lobe of the brain. In the vertebrate eye the fibers of the optic nerve spread out in the inner part of the retina, and are connected with several layers of ganglionic cells placed external to them. The light has to stream through the fibers and ganglionic layers to reach the visual cells—that is, the nerve terminals placed in the outer part of the retina. They may be regarded as epithelial cells, whose peripheral ends are developed into peculiar rod and cone shaped bodies, while their central ends are in physiological continuity with nerve fibrils. Each rod and cone consists of an inner and an outer segment. The outer segment is a pile of exceedingly thin, transparent, doubly refractive disks, colorless in the cone, but colored pink or purple in the rod. In man, the inner segment of both rod and cone is colorless and transparent. Its outer part appears to be a compact mass of fine fibrils that pass imperceptibly into the homogeneous looking protoplasm in the shaft of the cell. Owing to the position of the rods and cones, the light first traverses their inner, then their outer segments, and its unabsorbed portion passes on to the adjacent layer of dark brown pigment cells by which it is absorbed. It is not necessary for me to discuss the possible difference of function between the rods and cones. I may simply say that in the central part of the yellow spot of the retina, where vision is most acute, and from which we derive most of our impressions of form and color, the only sensory terminals are the cones. A single cone can enable us to obtain a distinct visual impression. If two small pencils of light fall on the same cone, the resulting sensory impression is single. To produce a double impression the luminous pencils must fall on at least two cones. That shows how distinct must be the path pursued by the nerve impulse from a visual cell in the yellow spot of the retina to a sensory cell in the brain. The impulses from adjacent terminals must pursue their own discrete paths through the apparent labyrinth of nerve fibrils and ganglion cells in the retina to the fibers of the optic nerve. How these facts bear on the theory of color sense will presently be apparent. Meantime I pass to the physical agent that stimulates the retina.

When a beam of white light is dispersed by a prism or diffraction grating, the ether waves are spread out in the order of their frequency of undulation. The undulations of radiant energy extend through a range of many octaves, but those able to stimulate the retina are comprised within a range of rather less than one octave, extending from a frequency of about 395 billions per second at the extreme red to about 757 billions at the extreme violet end of the visible spectrum. The ultra-violet waves in the spectrum of sun light extend through rather more than half an octave. Although mainly revealed by their chemical effects, they are not altogether invisible: their color is bluish gray. The only *optical*—that is, strictly *physical*—difference between the several ether waves in the visible or invisible spectrum is frequency of undulation, or, otherwise expressed, a difference in wave length. The *chromatic*—that is the color-producing—effects of the ether waves depend on their power of exciting sensations of color, which vary with their frequency of undulation.

Although the retina is extremely sensitive to differences in the frequency of ether waves, it is not equally so for all parts of the spectrum. In the red and blue portions, the frequency varies considerably without producing marked difference of color effect, but in the region of yellow and green, comparatively slight variations in frequency produce appreciable differences of color sensation. One striking difference between the effect of ether waves on the eye and sound waves on the ear is the absence of anything corresponding to the octave of tone sensation. The ether waves in the ultra-violet, which have twice the frequency of those of the red end of the spectrum, give rise to no sense of redness, but merely that of a bluish gray. Even within the octave there are no harmonies or discords of color sense corresponding to those of tone sensation.

Colors are commonly defined by three qualities or constants—hue, purity, and brightness. Their hue depends upon the chromatic effect of frequency of undulation or wave length. Their purity or saturation depends on freedom from admixture with sensations produced by other colors or by white light. Their brightness or luminosity depends on the degree to which the sensory mechanism is stimulated. The loudness of sound depends on the amount of excitement produced in the auditory mechanism by the amplitude of sound waves; but a sound with small amplitude of undulation may seem loud when the nerve apparatus is unduly sensitive. The brightest color of the spectrum is orange-yellow, but it does not follow that the amplitude or energy of the ether waves is greater than in the region of dull red. There is no physical evidence of greater amplitude in the orange-yellow, and its greater luminosity is no doubt purely subjective, and arises from the greater commotion induced in the sensory mechanism.

The theory of color sense long ago proposed by Sir Isaac Newton* is now commonly treated with what seems to me very undeserved neglect. Newton supposed that the rays of light induce vibrations in the retina which are transmitted by its nerve to the sensorium, and there induce different color sensations according to the length of the incoming vibrations—the longest producing sensations of red and yellow, the shortest blue and violet, those of medium length a sense of green, and a mixture of them all giving a sense of whiteness. At the beginning of this century Thomas Young proposed a theory which seems to have been intended as a modification of that suggested by Newton rather than as a substitute for it. Young supposed that the ether waves induce vibrations in the retina "whose frequency must depend on the constitution of its substance; but as it is almost impossible to conceive that each sensitive point of the retina contains an infinite number of particles, each capable of vibrating in unison with every possible undulation, it becomes necessary to suppose the number limited to three primary colors, red, yellow, and blue, and that each sensitive filament of the nerve may consist of three portions, one for each principal color."† Soon afterward he substituted green for yellow, and violet for blue, so that he came to regard red, green, and violet as the three fundamental color sensations, by mixture of which in varying proportions all other colors, including white, are produced. Young believed that his suggestion "simplified the theory of colors, and might therefore be adopted with advantage until found inconsistent with any of the phenomena."

Young's trichromic theory of color sense was adopted by Clerk Maxwell and Von Helmholtz, and underwent important amplification. Helmholtz suggested that the three sets of fibers supposed by Young to exist in the optic nerve are connected with three sets of terminals in the retina; that each terminal contains a different visual substance capable of being decomposed by light; that when the substance in the red nerve terminal undergoes chemical change its nerve fiber is stimulated, and the excitement travels to a cell in the brain by whose specific activity the sensation of red arises. In like manner, when the visual substances in the green and violet terminals are decomposed, nerve impulses travel through different fibers to different cells in the vision center, by whose specific activities the sensations of green and violet arise. With Helmholtz there was no question as to difference in quality of sensation depending on difference in frequency of nerve vibration arriving in the sensorium; no such hypothesis was entertained by him either for tone or for color sensation. With sight, as with hearing, he supposed that the function of frequency of undulation virtually stops at the nerve terminals in the eye and ear, and that the frequency of undulation of the physical agent has no correlative in the quality of motion passing from the receiving terminal to the sensory cell. He believes that the different frequencies of ether waves simply excite chemical changes in different nerve terminals. He expressly states‡ that the molecular commotion in the nerve fibers for red, green, and violet is identical in kind, and that its different effects depend on the specific activities of the different cells to which it passes in the sensorium. It is evident that Helmholtz entirely dismissed the Newtonian theory of the production of different qualities of color sense, and substituted for it the doctrine of his own great teacher, Johannes Muller.

The theory of Young and Helmholtz offers an explanation of so many facts, and has at the same time provoked so much criticism, that I must enter more fully into some of its details. On this theory, the sense of white or gray is supposed to result from a simultaneous and duly balanced stimulation of the red, green, and violet terminals. The red terminals are supposed to be excited chiefly by the longer waves in the region of the red, orange, and yellow, but also by the shorter undulations extending as far as Fraunhofer's line F, at the beginning of the blue. In like manner, the green terminals are excited chiefly by the waves of medium length, and to a less extent by the waves extending to C in the red, and by the shorter waves extending to G in the violet. The violet terminals are stimulated most powerfully by the shorter undulations between F and G, but also by the longer ones reaching as far as D in the yellow; therefore, optically homogeneous light from any part of the spectrum, except its extreme ends, does not usually give rise to a pure color sensation; all three primary sensations are present, and consequently the color inclines toward white—the more, the stronger the light.

The experimental facts in support of Young's theory are familiar to all who have studied physics. Compound color sensations may be produced by causing light of different wave lengths to fall simultaneously or in rapid succession on the same part of the retina. The commonest experimental device is to rapidly whirl disks with sectors of different colors, and observe the results of the mixed sensations; or to cause the images of colored wafers or papers to fall simultaneously on the retina by Lambert's method; or to transmit light through glass of different colors, and cause the different rays to fall on the same surface; or to mix pure homogeneous light from different parts of the spectrum. For obvious reasons, the last method yields the most trustworthy results. We cannot, by any mixture of homogeneous light from different parts of the spectrum, obtain a pure red or green sensation, and according to Helmholtz, the same holds true of violet. On the other hand, a mixture of homogeneous rays from the red and green parts produces orange or yellow, according to the proportions employed. A mixture of rays from the green and violet gives rise to intermediate tints of blue, and a mixture of red and violet light produces purple. Therefore, Young regarded red, green, and violet as primary sensations, and orange, yellow, and blue—just as much as purple—he regarded as secondary or compound sensations. Helmholtz discovered that to obtain a sense of white or gray it is not necessary to mingle rays from the red, green, and violet portions of the spectrum. He found that he could obtain a white sensation by mixing only *two* optically homogeneous rays from several parts of the right and left halves of the spectrum. The pairs of spectral colors which he found complementary to each other are, red and greenish-blue, orange and cyan-blue, yellow and ultramarine-blue, greenish-yellow and violet; the complement for pure green being found not in any homogeneous light, but in purple—a mixture of red and violet. The complementary colors may be arranged in a circle, with the complementaries in each pair placed opposite one another. Of course, the circle cannot be completed by the colors of the spectrum; purple must be added to fill in the gap between the red and violet. Helmholtz found no constant ratios between the wave lengths of homogeneous complementaries; and it is a striking fact that, while a mixture of the green and red or of the green and violet undulations gives rise to a sensation such as could be produced by rays of intermediate wave length, no such effect follows the mingling of rays from opposite halves of the spectrum. Pure green, with a wave length of 527 millionths of a millimeter, marks the division between the right and left halves. The mixture of blue from the right and yellow from the left side does not produce the intermediate green, but a sensation of white. A mixture of blue or violet and red produces not green, but its complementary—purple. On the trichromic theory, the sense of white produced by the mingling of any of these two colors is simply regarded as the result of a balanced stimulation of the red, green, and violet terminals.

But Young's theory is beset with serious difficulties. It implies the existence of three sets of terminals in the retina, and these must all be found in the central part of the yellow spot where cones alone are present. Three sets of cones there would be necessary to respond to the red, green and violet light, and a colorless pencil of light could not be seen uncolored, unless it falls on three cones, which we know from astronomical observations is not the case. Therefore, if there are three different terminals, it seems necessary, in the human retina at all events, that they should be found in every single cone in the yellow spot. But I cannot believe it possible that within a single cone there can be three sets of fibrils capable of simultaneous stimulation in different degrees, and of ultimately transmitting impulses through three different fibers to three different cells in the brain. That would imply a greater number of fibers in the optic nerve than of terminals in the retina, and we know that precisely the reverse is the case. The anatomical difficulty is therefore great, and I am unable to see how it can be surmounted.

The phenomena of color blindness also offer great difficulty. In several cases of apoplectic seizure it has happened that the center for vision on both sides of the brain has been completely or partially paralyzed by the extravasated blood. In such cases the sense of color may be entirely lost either for a time or permanently, while the sense of light and form remain—although impaired. The loss of color sense in some cases has been found complete in both eyes; in most of the recorded cases the loss of color sense was limited to the right or left halves of both eyes; that is, if the lesion affected the vision center on the right side of the brain, the right halves of both eyes were blind to all colors. That illustrates the fact that a sense of light does not necessarily imply a sense of color. The color sense probably involves a more highly refined action of the sensory cell than the mere sense of light and form, and is on that account more liable to be lost, when the nutrition of the sensory cell is interfered with. In the normal eye the peripheral zone of the retina is totally blind to color. If you turn the right eye outward, close the left, and then move a strip of colored paper from the left to the right in front of the nose, the image of the paper will first fall on the peripheral zone of the retina, and its form will be seen, though indistinctly, but not its color. It is difficult to say in that case whether the color blindness is due to the state of the retina or to that portion of the vision center in the brain associated with it. The absence of cones from the peripheral part of the retina has been assigned as the cause, but it is much more probable that the portion of the vision center associated with the periphery of the retina, being comparatively little used, is less highly developed for form sensation, and not at all for color sense. It is evident that the production of a sense of white or gray in the absence of all color sense is not to be explained on the theory that it results from a balanced stimulation of red, green and violet nerve terminals.

I need scarcely say that color blindness has attracted a large share of attention, not only because of its scientific interest, but still more on account of its practical importance in relation to the correct observation of colored signals. In 1855, the late Prof. George Wilson,* of this city, called attention to the growing importance of the subject. Some years ago Prof. Holmgren made an elaborate statistical inquiry regarding it at the instance of the Swedish government, and lately it has been investigated by a committee of the Royal Society of London, who have quite recently published their report.†

Although color blindness occasionally results from disease of the brain, retina or optic nerve, it is usually congenital. Total color blindness is extremely rare, but partial color blindness is not uncommon. It occurs in about 4 per cent. of males, but in less than 1 per 1,000 of females. Its most common form is termed red-green blindness, in which red and green sensations appear to be absent. So far as I can find, the first full and reliable account of the state of vision in red-green blindness is that given in 1859 by Mr. Pole,‡ of London, from an examination of his own case, which appears to be a typical case. The state of his vision is dichromic; his two-color sensations are yellow and blue. The red, orange and yellowish green parts of the spectrum appear to him yellow of different shades.

* See quotations from Newton made by Young in reference 2.

† Thomas Young, "On the Theory of Light and Colors," *Phil. Trans.*, Lond., 1802, p. 12.

‡ Von Helmholtz, *Handbuch der physiologischen Optik*, 2d edition, 1892, p. 350.

* Wilson, "Researches on Color Blindness," Edinburgh, 1855.

† "Report of the Committee on Color Vision," Proc. Roy. Soc., Lond., July, 1892.

‡ W. Pole, "On Color Blindness," Phil. Trans., 1859, vol. cxlix., p. 323.

Greenish-blue and violet appear blue, and between the yellow and blue portions of the spectrum, as it appears to him, there is a colorless gray band in the position of the full green of the ordinary spectrum. This neutral band is seen in the spectrum in all cases of dichromic vision. It may appear white or gray according to the intensity of the light, and it apparently results from an equilibrium of the two sensations; no such band is seen in the spectrum by a normal eye. Mr. Pole, in the account of his case given now three and thirty years ago, considered it impossible to explain his dichromatic vision on the commonly received theory that his sense of red is alone defective, and that his sense of yellow is a compound of blue and green. He believed his green quite as defective as his red sensation, and that yellow and blue are quite as much entitled to be considered fundamental sensations as red and green. He suggested that in normal color vision there are at least four primary sensations—red and green, yellow and blue. Prof. Hering is commonly accredited with the four-color theory, but it was previously suggested by Pole.*

A year after Pole's paper appeared, Clerk-Maxwell † published his celebrated paper on the theory of compound colors, to which he appended an account of his observations on a case of what he believed to be red blindness, but which we now know must have been red-green blindness. The spectrum appeared dichromic, its only colors being yellow and blue. His description of the case does not materially differ from that given by Pole; but Clerk-Maxwell believed in the trichromic theory of normal vision, and that red, green and blue are the three primary sensations; consequently, he supposed that the yellow sensation of a red-blind person is not pure yellow, but green.

It is evident that much depends on the question, "Is the yellow sensation of a red-green blind person the same as that of normal vision?" For many years it was impossible to give a definite answer to that question, but the answer can now be given, as we shall immediately see. Color blindness is frequently hereditary, and two or three cases are known in which the defective color sense was limited to one eye, while in the other eye color vision was normal. In such a case observed by Prof. Hippel, of Geissen, there was red-green blindness in one eye. Holmgren, who examined Hippel's case, has published an account of it.‡ With one eye all the colors of the spectrum were seen, but to the other eye the spectrum had only two colors, with a narrow gray band between them at the junction of the blue and yellow. The yellow seen by the eye with the red-green defect had a greenish tinge like that of a lemon, but in other respects the observations confirmed Pole's account of his own case.

Hippel's case seems to me important for another reason. By some it is believed that congenital color defect is due to the brain. If there had been defective color sense on one side of the brain, it would not have implicated the whole of one eye, but the half of each eye. Its limitation to one eye, therefore, seems to me to suggest that the fault was in the eye rather than in the brain.

Another interesting fact in this relation is that in every normal eye, just behind the peripheral zone of total color blindness, to which I have already referred, there is a narrow zone in which red and green sensations are entirely wanting, while blue and yellow sensations are normal. Possibly the red-green defect is due to an imperfectly developed color sense in the portion of the vision center connected with that zone of the retina, but Hippel's case seems to me to show that such defect might be on the retina.

It has probably already struck you that red-green blindness is really blindness to red, green and violet, that Young's three primary sensations appear to be absent, and the two remaining colors are those which he regarded as secondary compounds of his primaries.

That, however, is not all that is revealed by color blindness. There is at least another well known though rare form in which a sense of yellow, blue and violet is absent, and the only color sensations present are red and green. The defect is sometimes termed violet blindness, but the term is somewhat misleading. It is more in accordance with the fact to term it yellow-blue blindness; indeed, we would define it precisely by terming it yellow-blue-violet blindness. Holmgren § has recorded a unilateral case of that defect analogous to Hippel's case of unilateral red-green defect; we therefore know definitely how the spectrum appears to such a person. In the case referred to all the colors of the spectrum were seen with the normal eye, but to the other eye the spectrum had only two colors, red and green. The red color extended over the whole left side of the spectrum to a neutral band in the yellow-green, a little to the right of Fraunhofer's line D. All the right side of the spectrum was green as far as the beginning of the violet, where it "ended with a sharp limit (about the line G)."

If you turn to the Report of the Royal Society's Committee ‖ on Color Vision, you will find the spectrum as it appears to yellow-blue-violet blind persons. The plate agrees with the description of Holmgren's case already given; but you will not find a representation of the spectrum as it appears to those who are red-green blind, and as described by Pole and others. In place of it you will find two dichromic spectra, one with a red and blue half said to be seen by a green-blind, the other with a green and a blue half said to be seen by a red-blind person. We have copied the spectra for your inspection, and you will observe that yellow does not appear in either of them. I do not for a moment pretend to criticise these spectra from any observations of my own. I am aware Holmgren maintains that red-and-green blindness may occur separately; but, on the other hand, Dr. George Berry, an eminent ophthalmologist, has assured me that he has always found them associated. That statement was originally made by Hering.

Of the various methods of testing color vision, that suggested by Seebeck is most commonly employed. The individual is mainly tested with regard to his sense of green and red. He is shown skeins of wool, one pale green, another pink or purple, and a third bright red, and he is asked to select from a heap of colored wools, laid on a white cloth, the colors that appear to him to match those of the several tests. We have arranged such test skeins for your inspection, and have placed beneath each of them the colors which a red-green blind person usually selects as having hues similar to those of the test. It is startling enough to find brown, orange, green and gray confused with bright red; pale red, orange, yellow and gray confused with green; blue, violet and green confused with pink; but these confusions have all their explanation in the fact that the red-green blind have only two color sensations—yellow and blue, with a gray band in what should have been the green part of his spectrum.

We have now to show you another and far more beautiful method of ascertaining what fundamental color sensations are absent in the color blind. It is the method of testing them by what Chevreul long ago termed *simultaneous contrast*. If in a semi-darkened room we throw a beam of colored light on a white screen and interpose an opaque object in its path, the shadow shows the complementary color. If the light be red, the shadow appears green-blue; if it be green, the shadow appears purple or red, according to the nature of the green light employed. If the light is yellow, the shadow is blue; if it is blue, the shadow is yellow. We must remember that the part of the screen on which the shadow falls is not entirely dark; a little diffused light falls on the retina from the shadowed part, so that the retina and vision center are slightly stimulated, whereby the image of the shadow.

The experiment can be rendered still more striking, though at the same time a little more complicated, by using two oxy-hydrogen lamps and throwing their light on the same portion of the screen. If a plate of colored—say ruby—glass is held before one of the lamps, and an opaque object, such as the head of a T-square, is placed in the path of both lights, the shadow cast by the white light falls on a surface illuminated by a red light, and shows a deep red far more saturated than the surrounding surface of the screen where the red and white lights fall. The shadow cast by the red light shows the complementary bluish green; and the contrast of the two is exceedingly striking.

These experiments we have shown you point to some subtile physiological relations between complementary colors. A color sensation produced in one part of the vision apparatus forces, so to speak, the neighboring part, which is relatively quiescent, to produce the complementary color subjectively. I say *vision center* rather than *retina*, because, if one eye is illuminated with colored light while the other eye is feebly illuminated with white light, the complementary color appears in the center belonging to that eye. The sense of white appears to be a mysterious unity; if you *objectively* call up one part of the sensation, you call up its counterpart *subjectively*. If a color and its complementary counterpart be both displayed objectively at the same time, the action and reaction of effect afford a sensation far more agreeable than is producible by the objective display of only one of them. The agreeableness of the contrast of complementary colors, no doubt, springs from the harmony of effect. There is no harmony of color effect analogous to that of music, but there is harmony of a different kind, and that harmony is formed by the contrast of complementary colors.

Now, I imagine many of you have already anticipated the question, What information can simultaneous contrast give regarding the fundamental sensations of the color blind? From an extended series of observations Dr. Stilling,* of Cassel, has entertained that if a person cannot distinguish between red and green, no complementary color appears in the shadow when the inducing light is red or green, but if the inducing light is yellow or blue, the proper complementary appears in the shadow. If a person were blind to red, he never found the complementary green appear; if he were blind to green, he never found the complementary red appear. When the inducing light appeared colorless, the shadow was also colorless. Stilling, therefore, concluded that either the sensations of red and green or of blue and yellow were wanting at the same time, or all color sense was absent. It is difficult to see how these results are to be harmonized with the conclusions arrived at by the committee of the Royal Society.

Facts such as these are regarded by some as lending support to the theory of color sense proposed by Prof. Hering, of Prague.† He supposes that the diversity of our visual perceptions arises from six fundamental sensations constituting three pairs—white and black, red and green, yellow and blue. The three pairs of sensations are supposed to arise from chemical changes in three visual substances not confined to the retina, but contained also in the optic nerve and in the vision center.‡ He imagines that a sense of white results from *decomposition* induced in a special visual substance by all visible rays, and that the *restitution* of the same substance produces a sense of black. The sensations of the red and green pair are supposed to arise, the one from decomposition, the other from restitution of a second substance; while yellow and blue are supposed to result from decomposition and restitution of a third substance. From our knowledge of photo-chemical processes we can readily suppose that light induces chemical change in the visual apparatus; but that the wave lengths in the red and yellow parts of the spectrum induce *decomposition*, while the wave lengths in the green and blue induce *restitution* of substances, it is difficult to believe. How such a visual mechanism could work it would be difficult to comprehend; for example, if we look at a bright red light for a few moments and then close our eyes, the sensation remains for a time, but changes from red to green and then slowly fades away. According to Hering's theory, the green after-sensation results from the restitution of a substance decomposed by the red light. But if we reverse the experiment by looking at a bright *green* light and then closing our eyes, the after-sensation changes to *red*. The theory in question would require us to suppose that the green light builds up a visual substance which spontaneously decomposes when the eyes are closed, and so produces the red after-image. I confess that such a hypothesis seems to me incredible. Another remarkable feature of Hering's theory is that colors termed *complementary* ought to be termed *antagonistic*,* because they are capable of producing a colorless sensation when mingled in due proportions. If the complementary colors yellow and blue could, when mixed, produce black, they might well be named "antagonistic;" but since their combined effect is a sense of whiteness, and since the addition of them to white light increases its luminosity, it seems very difficult to comprehend on what ground the term *antagonistic* should be substituted for *complementary*. I confess I am quite unable to follow Hering when he supposes that three pairs of mutually antagonistic chemical processes are produced in the retina when white light falls on it, that these processes are all continued on through the optic nerve into the vision center, and there give rise to our different light and color sensations.

In 1881 Prof. Preyer † advanced a theory of color sensation, in which he supposes that in the retina there are four sets of cones arranged in pairs—one pair being excitable by the waves in the blue and yellow parts of the spectrum, the other pair being excitable by the red and green. He supposes that each pair of cones is connected with a ganglionic cell in the retina, and through that with one fiber in the optic nerve, which transmits the impulse to at least two cells in the vision center, in which two different qualities of sensation, red and green, yellow and blue, are severally produced. I confess, however, that I am not able to understand how nerve impulses received, say from the red terminal of a pair, can specially affect one of the cells in the nerve center to produce a red sensation. But if the red or green sensation were supposed to arise in the same central cell according to the frequency of the impulses transmitted from either terminal of the pair at the periphery, I should feel that an important difficulty had been removed from Prof. Preyer's theory.

It must be admitted that the production of nerve impulses within the terminals in the retina is almost as obscure as ever. It is still the old question, Does light stimulate the optic terminals by inducing vibration or by setting up chemical change? Whichever view we adopt, it seems to me necessary to suppose that all the processes for the production of nerve impulses can take place in one and the same visual cell, and are transmitted to the brain through the same nerve fiber; because the image of a colored star small enough to fall upon only one cone is seen of a fixed and definite color which does not alter when the position of the eye is changed. It seems to me that if there are special cones for red, green, yellow, and blue, the color of the star should change when its image falls on different terminals, but I am assured by Mr. Lockyer that such is not the case.

I referred to the sense of smell because it seems to me that we cannot in that case escape from the conclusion that the different sensations arise from different molecular stimulations of the same olfactory terminals.

From Lippmann's recent researches on the photography of color ‡ it appears that all parts of the spectrum can now be photographed on films of albumino-bromide of silver, to which two aniline substances, azaline and cyanine, have been added. It seems, therefore, reasonable to suppose that a relatively small number of substances could enable all the rays of the visible spectrum to affect the retina. Helmholtz believes that three visual substances would suffice; but if the primary sensations are to be regarded as four—red, green, yellow, and blue—at least four visual substances appear to be necessary; and I think we must assume that all of them are to be found in the same visual cell in the retina, and that the nerve impulses which their decompositions give rise to are all transmitted through the same optic fibers to the brain cells, there to produce a sense of uncolored or colored light. Evidently such a hypothesis is not altogether novel; it is essentially a return to that long ago suggested by Newton. The only difference is that light is supposed to induce photo-chemical changes in the retina, as Von Helmholtz suggested, instead of mere mechanical vibration, as Newton supposed. But if in the sense of smell nerve undulations are induced by mechanical vibrations of molecule acting on delicate hairs at the ends of cells, would it, after all, be unreasonable to suppose that within each visual cell there are different kinds of molecules that vibrate in different modes when excited by ether waves? Four or five sets of such molecules in each terminal element in the retina would probably be sufficient to project successively or simultaneously special forms of undulations through the optic nerve, to induce color sensations differing according to the wave form of the incoming nerve undulation. It seems to me that the question becomes narrowed down to this: Do the nerve impulses arise from mere vibration or from chemical change in the molecules of the nerve terminal? The photo-chemical hypothesis has much in its favor. We know how rapidly light can induce chemical change in photographic films, and we know that light induces chemical change in the vision purple in the outer segments of the rod cells in the retina. The fact that the cones contain no vision purple is no argument against the theory, for the inner segment of both rod and cone is by many regarded as the true nerve terminal, and there is no vision purple in either of them. The visual substances in the cones, at all events, are colorless, and the existence of them as substances capable of producing nerve impulses by chemical decomposition is as yet only a speculation awaiting proof. The fatigue of the retina produced by bright light is best explained on a chemical theory, but it could also be explained on a mechanical theory, for we must remember that, even if the nerve impulses produced in the visual cells were merely a translation of the energy of light into vibration of nerve molecules, the nerve impulse has to pass through layers of ganglionic cells before reaching the fibers of the optic nerve, and in these cells it probably always induces chemical change. The phenomena of partial color blindness

* W. Pole, "On Color Blindness," Phil. Trans., 1859, vol. cxlix., p. 331.

† Clerk-Maxwell, "On the Theory of Compound Colors," etc., Phil. Trans., 1860, vol. cl., p. 57.

‡ F. Holmgren, "How do the Color Blind see the Different Colors?" Proc. Roy. Soc., Lond., 1881, vol. xxxi., p. 302.

§ *Ibid.*, p. 306.

‖ See Reference 8., Plate I., No. 4.

* J. Stilling, "The Present Aspect of the Color Question," *Archives of Ophthalmology*, 1879, viii., p. 164.

† E. Hering, *Zur Lehre vom Lichtsinne*, 2d ed. Vienna, 1878.

‡ Hering, *ibid.*, p. 75.

* E. Hering, *Zur Lehre vom Lichtsinne*, 2d ed., p. 121.

† W. Preyer, "Uber den Fabren und Temperatur Sinn," etc., *Archiv fur Physiologie*, 1881, Band xxv., p. 21.

‡ G. Lippmann, "On the Photography of Color," *Comptes Rendus*, 1892, tome 114, p. 961.

could be explained on a photo-chemical theory by supposing that it arises from the absence of the substances required to produce the wave forms necessary for the color sensation which is defective, but the total color blindness at the anterior part of the retina is evidently a difficulty. How could we have a sense of light from that portion of the retina if all the visual substances are absent? That is one of the reasons why Hering supposed that a special visual substance is present everywhere in the retina, which by decomposition gives rise to a sense of light as distinguished from color. But even on the hypothesis we are pursuing, it is not necessary to suppose that all visual substance is absent, for color blindness in the front of the retina could be explained by supposing that color perception has not been developed in the corresponding portion of the vision center; and consequently, all nerve impulses coming from that part of the retina produce scarcely anything more than a sense of light.

If the photo-chemical theory is entertained, it seems necessary to suppose that there is some singular relation between the pairs of substances which respectively give rise to red and green, and yellow and blue, seeing that both members of a pair frequently, if not always, fail together.

It seems to me that the great difficulty arises when we consider the puzzling phenomena of contrast. If light of a particular wave length decomposes a special substance, and gives rise to say a sense of red, why does the complementary bluish green sensation appear in the vision center around the spot in which the red sensation arises? If the induced color were a pure green, one might attempt to explain it by supposing that a sympathetic change had been induced in a substance closely related to that suffering decomposition by the objective light, but no such simple explanation is admissible; the complementary contrast of red is not green, but a mixture of green and blue. The inadmissibility of such an explanation becomes still more apparent if we take pure green as the inducing color—the complementary contrast that appears is purple, which involves a blue or violet, as well as a red sensation. It matters not what inducing color sensation we adopt, the induced contrast is always the complementary required to make a sense of white.

George Wilson* long ago suggested that the simultaneous contrast probably arises from a "polar manifestation of force;" indeed, he regarded it as a "true, though unrecognized, manifestation of polarity." It is enough to mention that interesting suggestion, but I must not pursue it, for we are dealing with a problem that has as yet baffled the wit of man.

I have endeavored to place before you a subject that involves physical and physiological considerations of extreme difficulty. I have endeavored to show the nature of these difficulties, and although I have not attempted to solve them, I have at all events tried to show reasons why we should refer our different color sensations to differences in the incoming nerve impulses rather than to specifically different activities of cells in the visual center. I have not found it agreeable to point out the shortcomings of theories advanced by those for whom I have the deepest regard; but in the progress of scientific thought it is especially necessary to keep our minds free from the thraldom of established theory, for theories are but the leaves of the tree of science; they bud and expand, and in time they fade and fall, but they enable the tree to breathe and live. If this address has been full of speculation, I trust you will allow that the scientific use of the imagination is a necessary stimulus to thought, by which alone we can break a path through the dense thicket of the unknown.

THE NEW CONCENTRIC LENS.

THE construction of a lens to give a "positive" focus or that caused by rays of convergence has hitherto been obtained by the radius of convexity of one refracting surface being shorter than the concave one. As an illustration of this, take a simple lens of the form shown in the diagram (Fig. 1). If the meniscus form of this

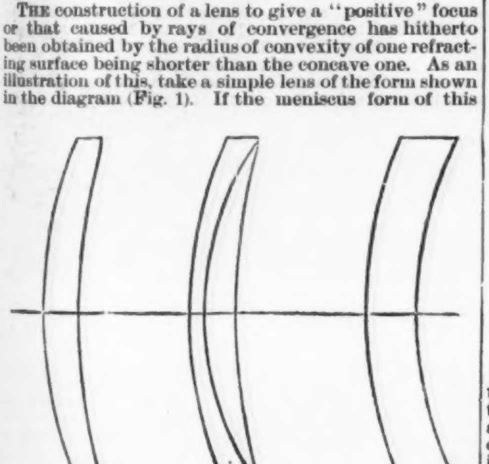


FIG. 1.

were to be altered by making the concave surface deeper, the lens would have no convergent focus at all, the rays would become divergent, and the result would become negative. Supposing this lens to be a compound made up of crown and flint glass, the latter having the greater refractive power, it will still be observed that the sum of all the positive curves is deeper than the sum of the negative radii. This form of construction is reversed in the "concentric," in which lens the convex surface has a longer radius than the concave, the diagram of which would at first sight lead one to expect a negative focus without any image; but this is not the case, for, by the selection of a suitable crown glass for the positive element, of higher refraction than the flint of the negative element, the rays are caused to converge, and by the special effect of refraction on the oblique pencils the lens, although of this peculiar form, gives a real image free from distortion on an absolutely flat field extending over a circle of about 75 deg., the margin being as sharply defined as the center; and, moreover, the whole is practically as equally illuminated as the theoretical limit will permit.

Every simple lens is represented by a system of prisms, whose angles are formed by the tangents of the radii. If two prisms or lenses are cemented together to form an achromatic prism, or lens, the angles of the two components are in a certain relative proportion, determined by the ratio of refraction and dispersion of the glass employed. When rays pass through such a lens, achromatic both at center and margin, these angles may then be greater, yet the relative ratio of both must be the same as those at the center, for if they differ in ratio, the marginal pencils will not be achromatic, and will be deviated in undue proportion, and besides color, will cause optical distortion. Taking an ordinary compound meniscus lens, whose curves are represented in the diagram (Fig. 2), we find that

FIG. 2.

the tangents of three curves are parallel at the center, so that there is no distortion or deviation of the direct incident pencils; but as we leave the center, we find that the tangents of the first and second curves approach one another, forming a wedge or prism, and the tangents of the second and third curves form a similar prism of smaller angle and in the reverse direction. This implies a greater power of the crown lens at the margin; and, as this has positive aberration the image produced by the margin of the achromat must be smaller than the central image, and hence barrel-shaped distortion and colored fringes are produced. In the diagram (Fig. 3) representing the "concentric" lens, it

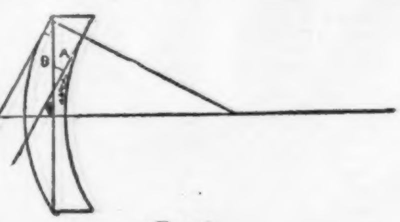


FIG. 3.

is evident, on consideration, that on account of concentricity the two tangents which, with the central plane, form the prisms, are always parallel and the angles formed in constant ratio. Such an achromat will therefore produce neither general distortion nor distortion of the colored images.

The field of the eccentric lens is practically illuminated equally all over. In all lenses the diaphragm reduces the amount of light in proportion to the deviation of the oblique cone of rays from the central cone (Fig. 4). This diminution of light toward the margin of

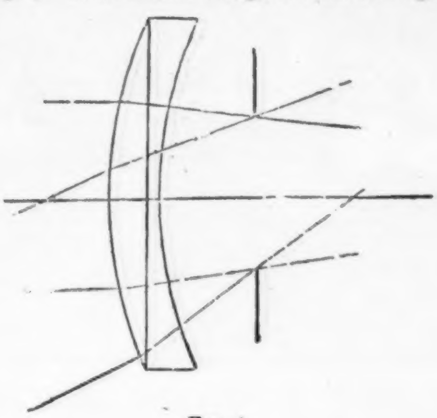


FIG. 4.

the field is small, however, when compared to that due to astigmatism and longitudinal spherical aberration in all ordinary lenses. The elliptical appearance of the diaphragm, caused by the oblique direction in which it is viewed, is exaggerated by the distortion in ordinary lenses, which have the property of diminishing objects in the horizontal diameter, whereas in the "concentric" lens, the diaphragm retains its proper shape until the light has nearly vanished. This is the effect of the opposite refraction due to the negative meniscus form having a positive focus, and which tends to open out—so to speak—the diaphragm to its normal circular form. An ordinary lens bringing its central rays to a sharp focus may be so constructed as to do so marginally also, but only on a curved field; a flat field being alone obtainable with such a lens by undue lengthening of the marginal pencils, resulting in astigmatism at the expense of definition. The rays do not actually meet in one point, so that the major portion is lost; or worse, they only assist to obliterate the sharpness of the actual working rays. In the "concentric," however, the whole pencil of rays goes to form the image equally at the margin as at the center.

Theoretically, a lens has no depth of focus; or, to speak more correctly, no depth of definition, for—optically—focus is a point. At the focal point the sharpest definition is obtained, but on each side there is a certain amount until the aberration becomes so great as to be perceptible. Ordinary lenses which come to focus sharp only in the center of the field, with vanishing distinctness toward the margin, are said to possess a certain depth of definition; but this is alone true for the center, the remainder of the field being only a compromise for definition at all. In the "concentric," however, we start with sharp and equal definition all over the field, due to its novel system of construction; and thus the definition of all objects situated equidistant from the principal focused object is equalized. Also, as there is no distortion or deviation of any portion of the cone of rays, they may be said to cling closer together for a longer distance on each side of the point of true focus. The "concentric," therefore, more nearly yields the theoretical amount of depth of definition (regulated more or less by aperture) than any other lens, and consequently may be said to possess greater depth of focus or definition over the entire field.

In practice it is found that the "concentric" lens is

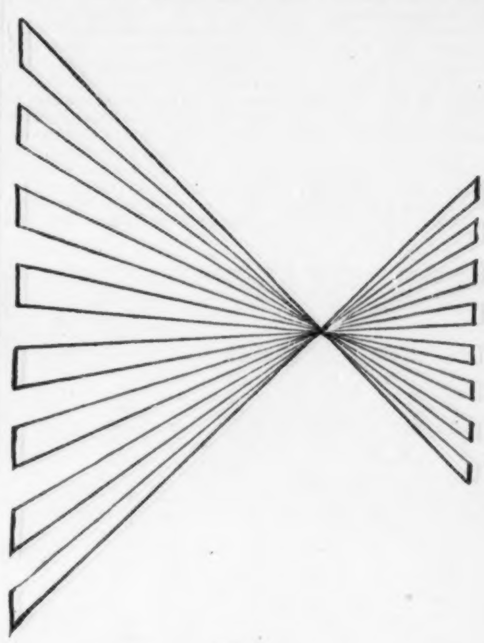


FIG. 5.

considerably more rapid than other lenses of equal aperture and focus. By referring back to the diagram (Fig. 3) shown to illustrate the loss of rays from spherical aberration and distortion, it is apparent that, the whole cone being brought to a focus in the "concentric" without distortion, the "concentric" consequently works quicker than lenses in which a portion of the rays only is used, and where the non-focusing rays merely interfere by throwing useless light into the shadows.

Having now drawn attention to some of the chief differences between the "concentric" and other lenses, it will be desirable, before proceeding to examine and compare these lenses optically, to explain the principle upon which the testing apparatus is constructed. We use a stand to carry a photographic lens in direct line between a stationary lamp and a concentric and aplanatic magnifier; the adjustments attached are to alter the distances between the positions for convenience of focusing. Having by this means examined the central pencil, the magnifier at the back is moved aside in a line toward the margin of the field, and a movable

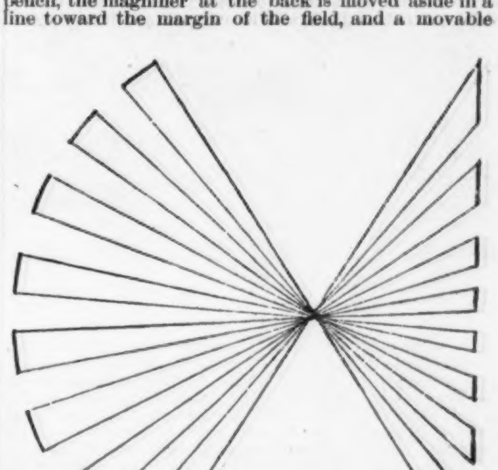


FIG. 6.

lamp placed at a distance is traversed on a plane parallel and at the same level as that in which the magnifier is moved, and which corresponds to the surface of the ground glass of a camera; the magnifier is moved sideways until the lamp and attached dial are visible, the angle subtended then being equal to that of the case may be, the diagonal of covering at that particular angle. The two diagrams herewith (Figs. 5 and 6) represent the principle upon which this method of testing is based, and it will be found that all that has been stated in connection with the "concentric" lens is optically correct, both when taken by itself and in comparison with other lenses. It should be mentioned that the magnifier being of the form of a sphere with concentric surfaces, the focal distance from the center

* Wilson, "Researches on Color Blindness," Edinburgh, 1855, p. 179.

is the same at all angles of obliquity, so that it requires no axial adjustment to meet the line of an oblique ray.—*The Amateur Photographer.*

THE DAHOMEY EXPEDITION.

THE Dahomey expedition has begun. As we are writing, the transport Mytho is not far from Kotonou and will soon land there the battalion of the foreign legion that it took on at Oran. We have already spoken of the wharf of Kotonou, which will peculiarly facilitate the landing of these troops. This wharf, which was begun hardly a year ago, at the suggestion of the two African explorers, Viard and Burdo, is now entirely finished. Up to new orders and for the needs of the military campaign that we have just undertaken, it is exclusively reserved for the state. It is through it that was landed the war *materiel* designed for the expedition.

The commander-in-chief of the expedition is Colonel Dodds, who belongs to the naval infantry and who has already made a long stay in Western Africa. He is a Senegal mulatto, and this quality has availed him not a little for recently recruiting a few hundred blacks of his country, who are the brightest of his effective natives. He was, moreover, commander of the troops at Saint Louis when Lieutenant-Colonel Terrillon was warring in 1890 against Behanzin. It was he who, at this epoch, proceeded to the sending of troops. He was better informed than any one else upon the affairs of Dahomey, and also was better fitted than any one else to draw up a plan of campaign, which chance and an intelligent choice force him to apply to-day.

The governor-general of the French establishments of Benin is Mr. Ballot. His career is both simple and very typical. A former sub-officer of the navy at Senegal, he, at the expiration of his leave of absence, entered the colonial administration and passed through the first stages of his career, and finally became director of political affairs at Saint Louis. It was thence that he was sent to Benin, where he had resided when the first events occurred in 1890. At that epoch his role was worthy of all praise. On the 20th of April of that year, Colonel Terrillon, who had left Porto Novo, so as not to be invested there by the Dahoman bands, ran up against these near the village of Atchoupa. His little corps of troops, formed in an impregnable square, had, for nearly two hours, to submit to the furious assaults of eight thousand Dahomans. On horseback, in the center of the square, near Colonel Terrillon and Chief-of-Staff Septans, Mr. Ballot, impassive and cool, had his helmet traversed by a ball, and provoked the admiration of the disciplinarians themselves—people who are not very impressible.

There is scarcely any need of adding that Mr. Ballot is beloved by everybody in Dahomey, except, perhaps, Behanzin. But he is especially beloved by Toffa, King of Porto Novo, who is the prime cause of all that is happening, and whom we present to our readers sitting in the midst of his court. In fact, Behanzin has always claimed Porto Novo, and Toffa considers himself as dispossessed of Dahomey. In order to balance things and settle the quarrel at its very source, it was seriously a question up to the beginning of 1890 of sending Toffa to live on the annuity that we would have allowed him in Guiana or elsewhere.

Fortunately, Mr. Ballot did not adopt this view, and Toffa, by his conduct, is giving us testimony of a true gratitude for having preferred him to Behanzin.

We present herewith a map of Dahomey, drawn from the most recent data, and which will permit our readers to follow with exactitude the operations that have just begun. We may take for the base of our troops' movements the course of the Ouémé, with Porto Novo for point of concentration. From Kotonou to Abomey, capital of Behanzin, it is about 48 miles. But the route is difficult. From Porto Novo, on the contrary, by the course of the Ouémé, upon which we have already three gunboats, the march upon Abomey is indicated without serious obstacles up to the ford of Tohoué. By such passage to Abomey it is a question of but a few hours.—*L'Illustration.*

KING TOFFA, OF PORTO NOVO (DAHOMEY), AND HIS COURT.

BOILER FEED WATERS AND INCRUSTATION.*

THE question of incrustation is to a very large extent a chemical one, though it also has its mechanical side; but it is to the former aspect that I propose to give my attention, suggesting that a paper devoted to the mechanical portion of the subject, from an engineering member of the institute, would be of great interest and utility. A careful investigation of the increased consumption of fuel resulting from various thicknesses of scale is greatly needed, as there are some very extravagant statements made on the subject; one experimenter stating that the fuel consumption is increased 150 per cent. by incrustation one-half inch in thickness. As every schoolboy knows, the first source of all natural water is the sea. By heat the water of the ocean is vaporized, and gradually the atmosphere becomes saturated with moisture, which falls to the sea and land again whenever the temperature of the atmosphere is reduced, either as rain or snow. According to the geological character of the land on which the rain or snow falls depend the properties of the resulting natural water. We are accustomed to divide water into two classes—soft waters, containing relatively small quantities of lime and magnesia salts in solution, and hard waters, containing relatively large quantities of these salts in solution. The following is a list of substances most commonly found in natural waters:

Scale Formers.

Carbonate of lime.
Carbonate of magnesia.
Sulphate of lime.
Silica.

The above substances, when present in quantity, readily form scale, while the substances given below, owing to their great solubility, rarely give scale, though it will be noted farther on that some of them by decomposition very often aid in forming incrustation:

Chloride of sodium, potassium, calcium, and magnesium.
Sulphates of sodium, magnesium, potassium.
Nitrates of sodium, calcium and magnesium.

Let us consider in detail the various salts mentioned above. Carbonate of lime is most abundant in nature, and is found in nearly all natural waters, either in traces or in quantity. Carbonate of lime itself is soluble in water only to the extent of two or three grains per gallon, and this solubility rapidly decreases as the temperature rises; but when the water also contains carbonic acid in solution, the solubility of the lime salt is enormously increased, and as much as eighty-five grains per gallon may be dissolved. The bicarbonate of lime thus produced constitutes the temporary hardness of water, so called, because on boiling the carbonic acid is expelled and the carbonate of lime is deposited. Hence a water of this class can be partially softened by boiling. The precipitation of the carbonate of lime commences at a temperature of about 150 deg. F., and is complete, according to M. Couste, at a temperature of 290 deg. F.—this is at a working pressure of about 60 lb. Where there is little sulphate of lime present in the water, in addition to carbonate of lime, the incrustation resulting from the latter salt may be reduced to a minimum by the judicious use of the blow-off cock, as the carbonate of lime falls as a soft sludge, which remains soft for a considerable period, and may, therefore, be blown out. Many of the carbonate of lime scales are produced by emptying the boiler while the plates and brickwork are hot, and the self sludge is thus baked on to the plates. The following are analyses of a carbonate water:

	(Analyst, Wanklyn.) Grains per Gal.
Carbonate of lime.	16·8
Carbonate of magnesia.	1·0
Sulphate of magnesia	1·2
Nitrate of magnesia	0·4
Chloride of sodium	1·3
	20·7

Carbonate of magnesia, like carbonate of lime, produces temporary hardness, being held in solution by carbonic acid. On boiling, the carbonic acid is expelled, and carbonate of magnesia is deposited. Unlike carbonate of lime, the decomposition may proceed farther, carbonic acid again being expelled, and magnesium hydrate resulting, which, according to Paul, acts as a powerful cement on any sulphate of lime that may be deposited. A sulphate of lime scale bound together by magnesium hydrate is exceedingly difficult to remove from the boiler plates. Calcium sulphate is undoubtedly the *bete noir* of all anti-incrustators, and gives endless trouble when present in the feed water of a boiler working at a high pressure, in quantity.

Calcium sulphate occurs in nature as gypsum—that is, sulphate of lime combined with two molecules of

* Abstract of paper read by Mr. Harry Silvester before the South Staffordshire Institute of Iron and Steel Works Managers.

water, $CaSO_4,2H_2O$; and, unlike carbonate of lime, is dissolved by water without the aid of carbonic acid, to a considerable extent. The solubility depends upon the temperature of the water, the maximum point of solubility being at 95 deg. F., when 178 grains per gallon are dissolved. As the temperature rises, the solubility diminishes, until at 212 deg. F. only 150 grains per gallon are dissolved. If boilers were worked at the ordinary atmospheric pressure and low pressures, with this comparatively high solubility, even with bad waters, it would be possible, by an intelligent use of the blow-off cock, to keep the plates free from scale, as the saturation of the water by the gypsum might be delayed for a long time. To prove this, I analyzed the water in a boiler working at 28 lb. to 29 lb. per square inch, the boiler having been working for many months without cleaning out.

Gypsum retains its two molecules of water at a temperature of 212 deg. F., but when the temperature rises to 260 deg. F., corresponding to a pressure of about 35½ lb. to the square inch, it begins to lose this water, and at 303 deg. F., corresponding to a pressure of about 70 lb. per square inch, is converted into anhydrous sulphate of lime, which is practically insoluble in water. The deposition of sulphate of lime is, therefore, due to the loss of the two molecules of water, the precipitation commencing at about 260 deg. F., and being complete at about 303 deg. F. The anhydrous salt, along with magnesia and the other formers, rapidly sets into a hard scale, which is, no doubt, familiar to all of you.

Alkaline waters, owing their alkalinity to carbonate of soda, are occasionally met with as natural waters, and are very objectionable for use in the boiler. An analysis of such a water from a London artesian well is given in the following table:

	(Analyst, Matthews.) Grains per Gal.
Carbonate of lime	11·5
Carbonate of magnesia	7·8
Sodium chloride	6·4
Sodium nitrate	0·2
Sodium sulphate	4·8
Sodium carbonate	8·3
	39·0
Alkalinity as carbonate of lime	29·7

It is to be observed that these waters frequently contain carbonates and sulphates of lime, and at the same time carbonate of sodium. This state of things can only exist for a time, for immediately the water is heated a reaction takes place by which the lime salts are precipitated.

That such is possible, however, will readily be acknowledged by all who have attempted to precipitate, completely in the cold, sulphate of lime, by means of soda ash from the canal water of the district; there may be excess of carbonate of soda present, but the whole of the lime is not precipitated until heat is applied.

A concentrated solution of carbonate of soda rapidly attacks boiler fittings. The small amount of copper dissolved from the latter in contact with the iron plates is, in its turn, precipitated, an equivalent quantity of iron passing into solution. With concentrated alkaline waters a series of reactions may thus be set up, which will rapidly produce pitting of the plates. The last form of deposit to which I shall allude before considering the various methods used for softening water is a dangerous form of incrustation, which has followed the introduction of high pressure steam. Below is an analysis of this particular kind of scale:

	Per cent.
Sulphate of lime	69·50
Carbonate of lime	2·95
Magnesia	1·45
Oxide of iron	0·66
Alumina	0·64
Silica	13·85
Fatty acid	3·60
Organic matter and combined water	6·87
Moisture	0·48
	100·00

The fatty acids and unsaponified oils present in the two incrustations are derived from the oils used to lubricate the cylinder of the engine, and are communicated to the feed water, when the exhaust steam from a non-condensing engine is used to heat the feed, or the feed is drawn from the hot well of a condensing engine.

We have now considered the most important mineral constituents of natural waters, and also other substances rendering the water unsuitable for the purpose of raising steam. We have noted the wide variation that may occur, both as regards the kind and quantity of mineral water in solution. It follows from these variations that no one specific can be efficacious with all waters as a preventive of incrustation. The attempt to obtain such a substance will be as successful as were the efforts of the old alchemists to discover the principle that was to transmute the base metals into the noble ones.

The treatment to which boiler waters are subjected to prevent scale may be divided into two classes.

(1) Treatment of the water with chemicals before it enters the boiler.

(2) The introduction of chemicals into the boiler itself.

Without doubt, wherever financial considerations will allow, treatment of the water by the first plan is always to be preferred, as it allows of the careful adjustment of the chemical added, and the precipitated salts do not enter the boiler at all. Numerous companies are adopting this plan at the present time in preference to the use of compositions, and it is evident from the number of firms making a specialty of water treatment that precipitation outside of the boiler is gaining ground.

The oldest process for the softening of water is Clark's, and is applicable, as originally introduced, to waters owing their hardness to carbonate of lime and carbonate of magnesia. As we have already noticed, these salts are held in solution by dissolved carbonic acid, and if we can drive out or absorb the carbonic acid the carbonates are precipitated, not entirely, but with the exception of two or three grains per gallon. Clark's process consists in the addition of sufficient lime, preferably in the form of lime water, to combine with the carbonic acid, when the following change occurs:

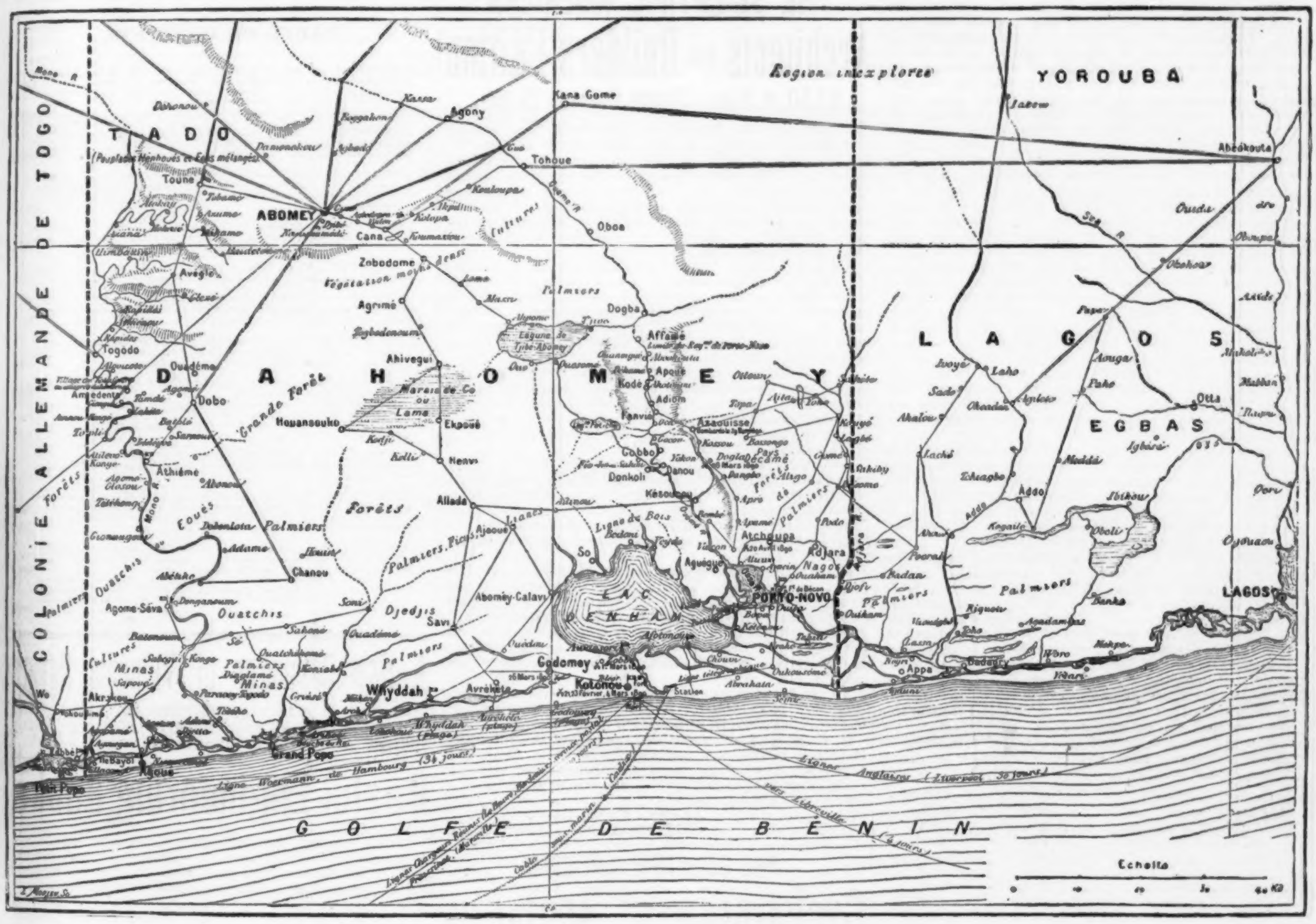
Soluble.				Insoluble.
Carbonate of lime $CaCO_3$	+ Carbonic acid CO_2	+ Lime CaO	=	Carbonate of lime $2CaCO_3$

According to Dr. Frankland, to soften 700 gallons of bicarbonate water for this process, 1 oz. of quicklime is required for each part of temporary hardness in 100,000 parts of the water; that is, a water containing 15 grains of carbonate of lime per gallon would require 21·1 oz. of lime for every 700 gallons in order to soften it, or 30·1 per 1,000 gallons.

Where waters owe their hardness to both carbonate and sulphate of lime the solution of lime water is not infrequently mixed with caustic soda, or, as we have seen above, carbonate of soda, the proportions of these substances depending on the quantity and relative proportions of the incrustating salts. Sodium hydroxide may, with advantage, be used alone where the amount of bicarbonate of lime is present in quantities equivalent to the amount of sulphate of lime, that is, in the proportion of 144 parts of bicarbonate to 136 parts of sulphate.

Other reagents besides caustic soda, caustic lime and carbonate of soda have been proposed for the softening of water, notably phosphate of soda and chloride of barium. But, chiefly on account of their cost, they have not come into general use like the first mentioned substances. At the present time phosphate of soda is quoted at \$76.50—15 pounds 15 s.—per ton, and its use as a softener, except for special purposes, is therefore out of the question. Barium chloride, for a similar reason, is also restricted in its application, the present value of it being \$37.60—7 pounds 15 s.—per ton. Its action consists in the precipitation of the sulphates, as sulphate of baryta. The sulphuric acid in combination with soda is thus precipitated, as well as that in combination with lime, which means unnecessary consumption of the reagent. A further objection to the use of barium chloride is its inability to remove magnesium from the water, this metal being left in the water in the objectionable form of chloride of magnesium.

We now come to consider the prevention and reduction of scale by the far more generally adopted plan of passing some chemical either directly into the boiler at the commencement of a working week, or continuously, along with the feed. The latter plan is infinitely to be preferred, wherever possible, particularly if the chemical and feed pass through the heater, the softening of the water then taking place to a certain extent outside the boiler, large quantities of the precipitated salts remaining in the heater. The practice of adding to the boiler at the commencement of the week what is judged to be sufficient composition for several days is not to be recommended, causing, in the case of caustic compositions, the boiler to "kick" and also the



GENERAL MAP OF DAHOMEY.

fittings to be attacked and corroded by the alkali. This custom might be paralleled in ordinary life by a man taking his breakfast, dinner, tea and supper at a sitting. Such a practice would certainly save time and trouble.

There are innumerable substances in the market as boiler compositions, the following being by no means a complete list of the substances which form the basis of these concoctions, or have been recommended for use: Caustic soda, soda ash, phosphate of soda, silicate of soda, tannate of soda, fluoride of sodium, chloride of ammonia, sulphate of soda, potatoes, starch, dextrine, molasses, sugar, tannic acid, barks, sumac, gelatin, etc.

The above substances roughly fall into three divisions, according to the manner in which they act, as regards the prevention of scale: (1) Those substances which aim at precipitating the incrusting salts from the water, in such form that they may be blown out of the boiler by a judicious use of the blow-off cock. To this class belong the inorganic compounds such as the salts of sodium. (2) Those substances which have a mechanical action, rather than a chemical one, preventing the precipitated salts from uniting into a hard mass. To this class, potatoes, dextrine, starch, etc., may be assigned. (3) Those substances which, when added to the water, increase the insolubility of the incrusting salts, and thus either entirely or partially prevent their deposition. To this class may be assigned gelatin and also sugar, which, with lime salts, forms soluble saccharate of lime. Of course, these divisions are not hard and fast ones, for substances classed as merely mechanical no doubt react chemically as well, while the gelatin and sugar act mechanically in preventing the hardening of any deposit that may form. In practice it is usual to mix the precipitating salts with some form of organic matter, no doubt in some cases with the twofold object of disguising the weakness of the solution, and also preventing the adhesion and cohesion of the precipitated salts, and where the organic matter is harmless such an addition for the latter purpose is decidedly to be recommended.

Caustic soda or carbonate of soda along with some form of organic matter enters very largely into the majority of compositions on the market. The use of these substances with carbonate waters is not to be recommended, as the alkali, after doing its work, still remains in the water, and, if allowed to become concentrated, causes priming, and also attacks the fittings, setting up a series of reactions, to which allusion has already been made. Where sulphate of lime is also present in the water, in quantities in excess of the carbonate, then soda ash is no doubt a most useful composition, as the carbonate of soda remaining in solution throws down insoluble carbonate of lime, sulphate of soda going into solution. It is generally advisable to have organic matter present in the composition to mechanically prevent the precipitated carbonate from cohering and adhering. With acid waters, carbonate of soda gives excellent results, when added in suitable proportions.

Silicate of soda or soluble glass is not infrequently used as an anti-incrustator. Its action being the precipitation of the lime and magnesia as silicates. Mr. Paul states that in certain cases the precipitate sets hard, but the use of organic matter along with it would, I believe, effectually prevent this. Of course, excess must be carefully guarded against.

Tannate of soda is highly recommended as a boiler composition, its action being the precipitation of the lime as tannate of lime. This separates as a loose deposit, which does not adhere to the plates, and can therefore be blown out. Tannic acid, uncombined with soda, has been used, but it is found to have an action on the plates, and therefore is not to be recommended. The cost of tannate of soda constitutes the difficulty of bringing it into general use, and many of the so-called tannate of soda compositions are merely exhausted tan, that is, tan from which the tannin has been extracted, boiled with soda.

Below are two analyses of this class of composition, and you will notice that the percentage of tannin is not very great.

(Analyst, Tatlock.)	No. 1 per cent.	No. 2 per cent.
Caustic soda	12·30	11·44
Chloride of sodium	1·24	1·22
Sulphate of sodium	0·68	0·72
Tannin	6·65	6·36
Carbonate of lime	0·48	0·40
Organic matter	19·60	18·99
Water	59·05	60·87
	100·00	100·00

Such substances as catechu, nut galls, oak barks, sumac, and logwood contain tannic acid, and owe their value as anti-incrustators to this substance, which acts chemically, and in a less degree to other extractive organic matter, which acts mechanically.

Sodium fluoride is given by Prof. Lewes as being highly efficient for the prevention of incrustation. Among its advantages may be mentioned a very low combining weight, and the rapidity and completeness with which the lime and magnesia salts are precipitated, the precipitate showing no tendency to harden. Like several other very valuable anti-incrustators, its cost renders the extensive application of it too great a luxury. There appears, however, to be prospects of this being sufficiently reduced to bring it into practical use.

Potatoes, dextrine, starch, etc., are frequently used in boilers, with or without soda. They form a slimy deposit on the precipitated salts, thus preventing their setting into a hard scale. It has already been noted that sugary matter owes its efficiency as an anti-incrustator to the formation of soluble saccharate of lime with the incrustating salts, thus preventing their deposition.

Gelatin also acts by retaining the sulphate of lime contained in the water in solution, that substance being more soluble in a water containing gelatin. It is said by Mr. Paul to give good results with a carbonate water containing at the same time a small amount of sulphate of lime. On heating the water, carbonate of lime is precipitated along with some gelatinous matter, the sulphate of lime being retained in solution, and thus the hardening of the carbonate precipitate is prevented.

In many quarters compositions are in bad odor, and are regarded as doing no good, or positively more harm than good. That such is very often the case is beyond doubt, because one composition is recommended for every class of water, and we have seen how unsuitable some chemicals are for particular waters, *e. g.*, caustic soda for carbonate waters. Another fruitful source of failure is the inadequacy of the quantity of chemical used to deal with the amount of mineral matter existing in the water. The fact is, the price charged for most compositions renders their application in anything like practical quantities far too expensive a process and a thorough revision of charges is sadly needed. One hundred and six grains of carbonate of soda will precipitate the lime of 136 grains of sulphate of lime, and the quantity of solution used should be calculated on reactions of this kind, together with a knowledge of the amount of feed water required per hour for the boiler, and not on the horse power of the boiler. Directions as to the quantity to be used of composition based on the horse power are very often issued with the concoctions, and are practically valueless, as the mineral matter to be precipitated varies widely with different waters, and of this such directions take no account.

The use of chemicals in the boiler, where they are exactly suited to the water, in kind and quantity, is but an imperfect remedy, and it is certain that the empirical application of compositions can rarely be beneficial, but, on the contrary, may intensify the evils that their addition is intended to minimize.

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TABLE OF CONTENTS.